MAYORAL FLOOD TASKFORCE

Final Report
Part B: Issues and Options

August 2014

Christchurch City Council

Trim 14/903663

Christchurch City Council

Document Control

Document title:	Mayoral Flood Taskforce Temporary Flood Defence Measures Final Report – Part B: Issues and Options
Revision:	Final Rev A
Date:	8 August 2014
TRIM ref:	14/894027

Document history and status

Revision	Date	Description	By	Review
Final Draft	4 July 2014	Final draft for internal review only	Peter Christensen	Mike Gillooly Tom Parsons Sylvia Maclaren
Final Rev A	8 August 2014	Final report	Peter Christensen	John Mackie

List of Contributors

Mike Gillooly	Christchurch City Council	Stuart Sandy	Aecom
Terry Howes	Christchurch City Council	Andy Gibson	Aecom
John Mackie	Christchurch City Council	Peter Christensen	Aurecon
Helen Beaumont	Christchurch City Council	Jeanette White	Aurecon
Leah McBey	Christchurch City Council	Regan Smith	Aurecon
Dean Ewen	Christchurch City Council	Anna Lindgren	Aurecon
Tim Ayers	Christchurch City Council	Thomas Chabanne	Aurecon
Peter Wehrmann	Christchurch City Council	Irfon Jones	Aurecon
Paul Dickson	Christchurch City Council	Jan Kupec	Aurecon
Stephen Adam	Christchurch City Council	Zoe Pletz	Aurecon
Graham Harrington	Christchurch City Council	Tom Revell	Aurecon
Paul Cottam	Christchurch City Council	Leon Gerrard	Aurecon
Luke Merryweather	Christchurch City Council	Cameron Irvine	Aurecon
Lisa Perry	Christchurch City Council	Camilla Gibbons	Aurecon
Dave Rowlands	Christchurch City Council	Richard Simpson	Aurecon
Tony Liu	Christchurch City Council	Jonathan Broome	Bond Construction Management
David Pinkney	Christchurch City Council	Vance Perrin	City Care
Tom Parsons	Innovate Consulting Ltd	Brian Keown	City Care
Sylvia Maclaren	Jacobs	Helen Shaw	Environment Canterbury
Gareth Taylor	Jacobs	Matt Thomas	Garage Consulting Company
Ben Fountain	Jacobs	Kate Dawkings	GHD
Matt Shepherd	Jacobs	Jalan McGrory	GHD
Matt Bot	Jacobs	Julia Riding	GHD
AJ Weir	Jacobs	Matt van der Peet	GHD
Jim Bell	Jacobs	Stephen Bensberg	L G Consulting Limited
Dave Compton-Moen	Jacobs	Chris Maguire	MWH
Ramana Sonthi	Jacobs	Simon Dellis	Opus
Matt Prosser	Jacobs	Mark Groves	Opus

Disclaimer

This report contains technical information prepared by the Mayoral Flood Taskforce. As of 8 August 2014 the Christchurch City Council has yet to make any decisions on the report, and the matters contained in the report. The report was prepared on the basis of the best available information at the time. That information may be subject to change (in whole or in part) and the Council does not represent or warrant the completeness or accuracy of the information within the report.

Christchurch City Council has no control over and is not responsible or in any way liable, to any person or entity that chooses to rely upon the information, or for any errors, omissions, or inaccuracies, whether arising from negligence or otherwise or for any consequences arising therefrom.

Any person or entity wishing to rely on the information is advised to seek independent advice as may be necessary.

Foreword

Those of us who haven't experienced the devastation of flood waters entering our homes would find it hard to imagine what it is like.

Over the last twelve months I have met many of you in school and church halls. I have sat around the kitchen table in your flooded homes and heard your stories, your frustration and your anger. I have watched, helpless, as you evacuated your homes, carrying your children to the car in the middle of the night.

This report tells us for the first time how big the problem is across the city for our most vulnerable homes. It tells us more of the human dimension – the impacts on children, families, and the elderly, and how we as a Council and as a community can help.

It offers viable solutions for some, and for others there is still more work to do. Some will be surprised that they are not represented in this report and for that I apologise in advance. In the time available it just wasn't possible to include everyone, and I am acutely aware of some of the shortcomings of the data that we are dealing with.

There are solutions and they vary. The focus of the Taskforce was on what we could do to help until more permanent solutions are put in place.

Some things can be done immediately, some will take time, and some will take a lot more dialogue with other agencies and Central Government.

I would like to thank all my colleagues in this Taskforce for their huge effort and commitment over the last two months.

Mike Gillooly

Land Drainage Operations Manager and Task Force Leader

4 July 2014

Acknowledgements

The team would like to acknowledge the support provided from the wider Council, SCIRT, other stakeholder organisations (ECan, EQC and CERA), organisations of the Taskforce members and most importantly, the members of the public who shared their knowledge.

Table of Contents – Part B: Issues and Options

The Taskforce Final Report also consists of the following companion volumes:

PART A: KEY FINDINGS AND RECOMMENDATIONS

Includes the Executive Summary, key findings, lists of recommendations, and costs and implementation programme

PART C: APPENDICES

Appendix A	Temporary Flood Defence Options
Appendix B	Detailed Area Reports
Appendix C	Wastewater Overflows in Flood Events

Section A: Context

This section sets out the reasons why, and issues caused by, the regular flooding experienced since the earthquakes in Christchurch.

1 Historic and recent flooding in Christchurch

The frequency of widespread flooding since the Canterbury earthquake sequence is primarily due to a series of large rainfall events. However, earthquake damage has made the effects more serious, particularly in places such as Flockton Basin. This section summarises the causes the geophysical context of post-earthquake flooding events.

1.1 Post-earthquake rainfall in context

Analysis of the Christchurch rainfall record has been undertaken to correlate rainfall events with known flood events. It was concluded that events with more than 75 mm of rain in 40 hours provide a good match of the occurrence of flooding. Christchurch has experienced six such flood events since the Canterbury earthquake sequence with four in 2014 alone (Figure 1**Error! Reference source not found.**). This compares with three in 1986 and two in 1975. The average interval between floods in the 52 year period is less than one every two years. Therefore it is clear that since the earthquakes the number of high depth rainfall events and total rainfall depth is more than usual. For instance, Christchurch rainfall in March and April 2014 was by far the highest recorded at the Christchurch Gardens rainfall gauge since records began in 1864. The combined total of 431.8mm significantly exceeds the previous highest March-April rainfall of 306.5 mm recorded in 1951.

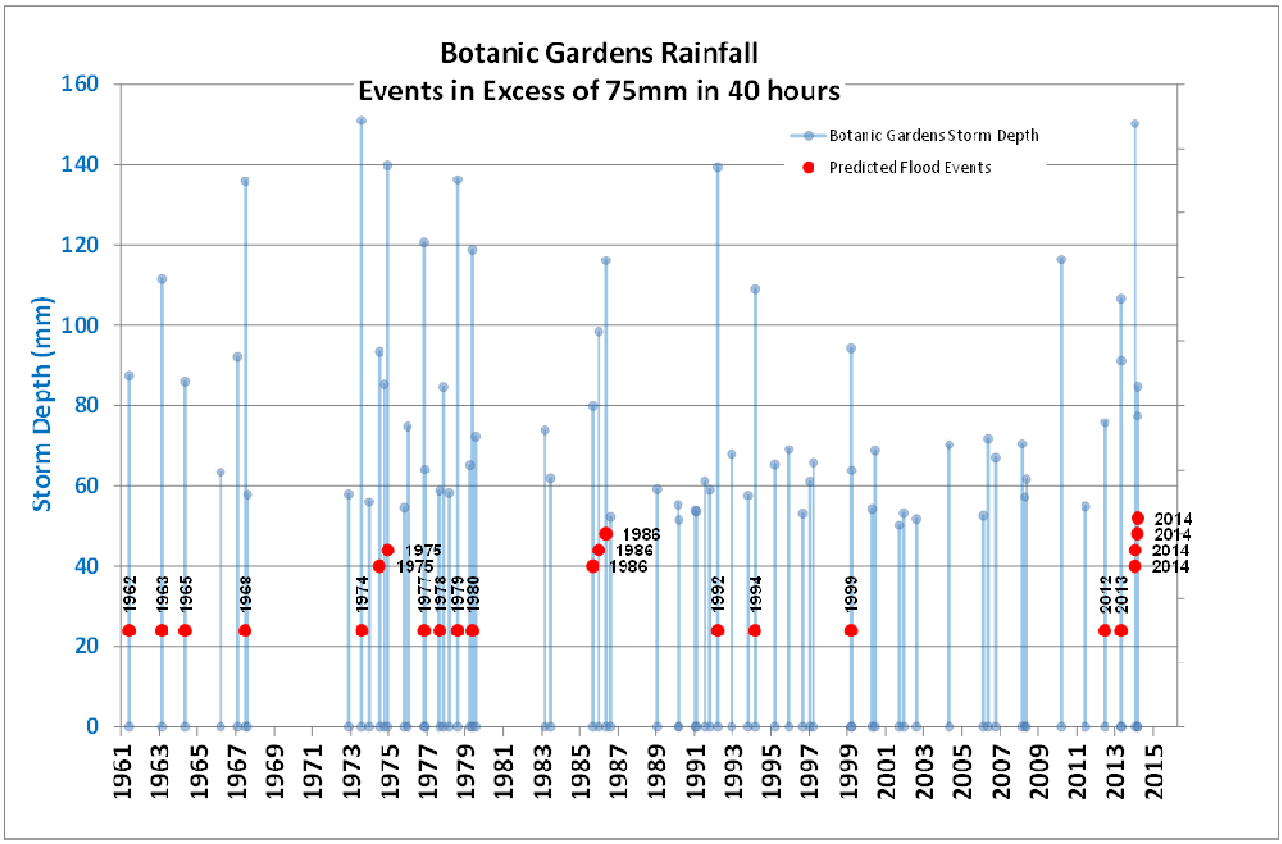


Figure 1 Christchurch flood events identified from rainfall event analysis

While Christchurch has experienced four rainfall events with a depth greater than 75mm in 2014, only one of these events (5 March 2014) had a longer duration depth that was considered to be above the usual design standard for flooding above the floors of houses. This design standard is commonly known as a 1 in 50 year flood (strictly speaking, the flooding that arises from a rainfall event with a 2%

probability of occurring annually). Figure 2 illustrates the significance of the March rainfall event compared to previous Christchurch storms.

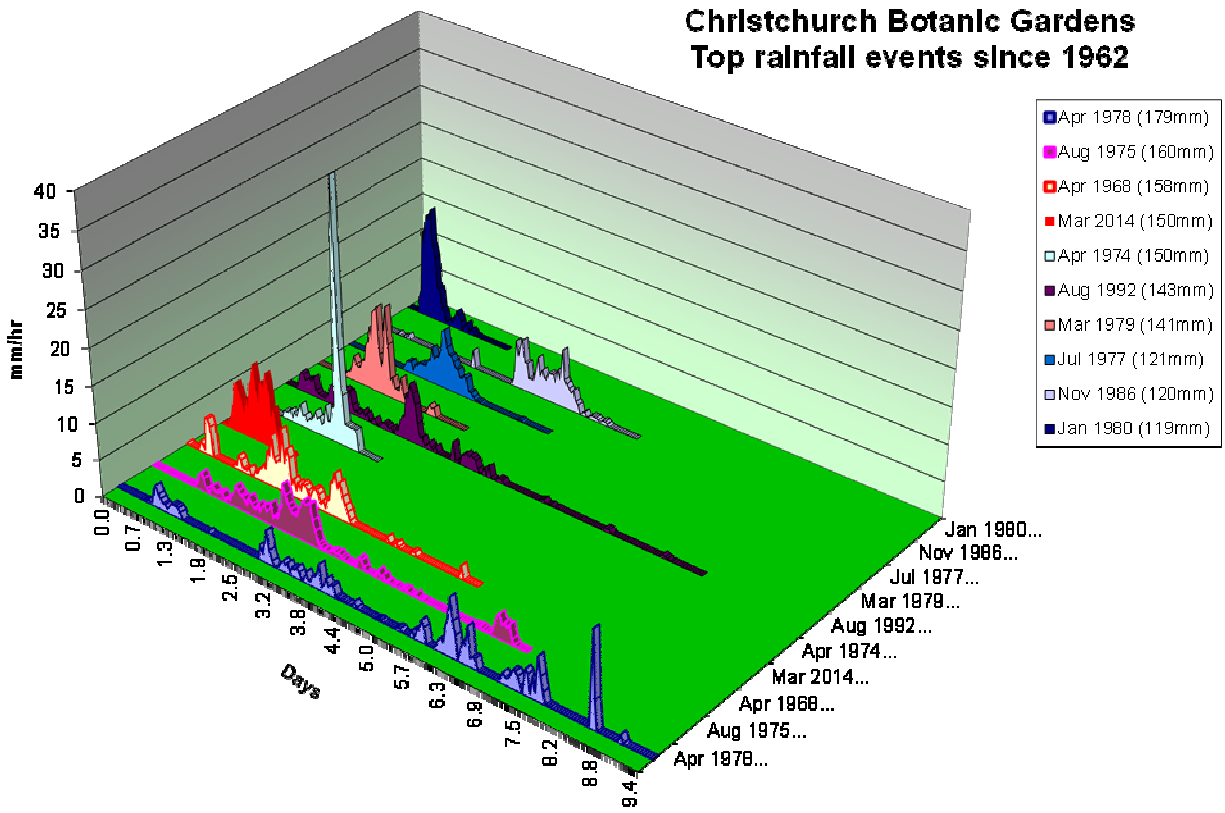


Figure 2 Largest 10 rainfall events at the Botanic Gardens since 1962 based on rainfall depth

Flooding from the 5 March 2014 storm was caused by a moderate to high intensity rainfall over more than 24 hours. This caused widespread flooding in the Heathcote and Avon catchments but less so in the Styx catchment where there was less rain. The storm also had strong winds which broke tree branches and uprooted trees. These and other debris partly blocked channels and screens on stormwater intakes and contributed to higher flood levels. In the Lower Heathcote non-return valves were kept partially open with debris, allowing water to flow into the stormwater system and contribute to flooding behind the stopbanks.

The storm coincided with a high tide nearly 0.5 m above the expected height due to barometric and wind set-up effects. Flood flows were also impeded in some areas by earthquake repairs (e.g. the Colombo Street Bridge and sewer repairs in the Lower Heathcote shown in Figure 3) which caused higher flood levels in these rivers.

Note that the flooding resulting from rainfall events however also depends on storm duration and volume. Both the February and March 2014 rainfall events only have a similar one percent probability of occurring in any given year. The February event was shorter with a lower total depth (30mm in one hour at Wigram and Ilam) while the March event was longer with a greater depth (148mm in 24 hours at the Botanic Gardens). Therefore although the intense rainfall in February overwhelmed the local drainage network and flooded roads, it did not result in widespread flooding of areas such as Flockton. It is generally the longer storms with a greater total depth that have however caused widespread flooding because of the large volumes of stormwater runoff.

Figure 3 Earthquake repairs in waterways

1.2 Earthquake effects

The earthquakes have caused widespread liquefaction of the loose, saturated soils that lie beneath the Plains. This liquefaction has often resulted in physical damage to the land in the form of lateral spreading, land cracking, undulations, ponding, local settlement, groundwater springs and inundation by ejected sand and silt.[1] Infrastructure damage has also occurred in many areas.

Increased flooding is likely in many of the land damaged areas. In tidal areas since the tide level has remained unchanged and land levels have dropped, the effect is similar to that produced by sea level rise, with tidal water restricting the flow of water causing flooding upstream. This has occurred in areas around the lower rivers and the Estuary, or in areas which discharge to these (including the Flockton Basin). To regain this lost capacity channels need to be widened or pumped. Land rise around Ferrymead and land fall toward the city has also made the areas between Woolston and the central business district more vulnerable to flooding.

Many waterways have been subjected to increase siltation due to an increased load from liquefaction and lower velocities where the grade is reduced. This reduces waterway capacity and increases flood risk. Lateral spread of banks also reduces the waterway capacity. Damage to the pipe network has also been identified as a contributor to flooding, though in general this is minor compared to the other effects.

Flooding in the Residential Red Zone (RRZ) was not studied by the Taskforce as the future use of this area is not determined.

Since the earthquakes, the Dudley Creek Catchment which includes the Flockton area, has been extensively investigated as part of the LDRP. Computer modelling and observations of several flood events have given an understanding of the changes in the depth and extent of flooding extents as a consequence of earthquake effects. Parts of this catchment have settled by up to 0.4m.

Areas flooded in a flood with a 10 year average recurrence interval were hydraulically modelled based on pre- and post-earthquake land levels (Figure 4 and Figure 5). This clearly shows an increased flood extent *and* depth across the Flockton Basin and other areas alongside the waterway.

[1] *Canterbury Earthquakes 2010 and 2011: Land report as at 29 February 2012,* Tonkin and Taylor.

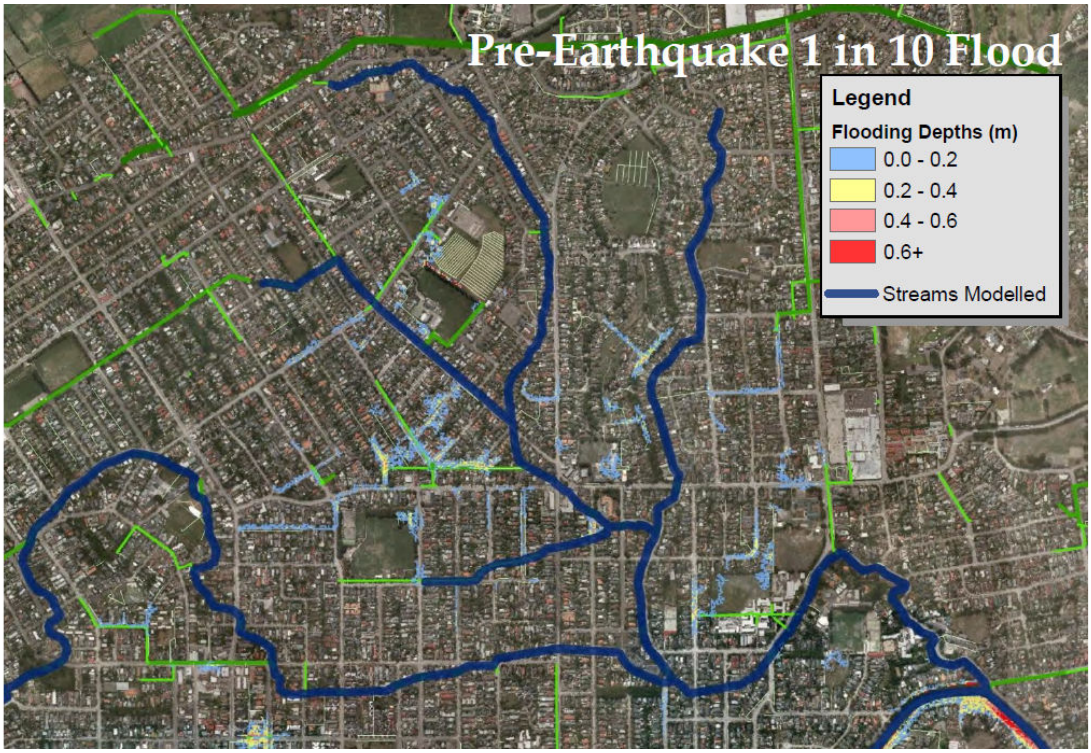


Figure 4 Pre-earthquake 1 in 10 year flood extents

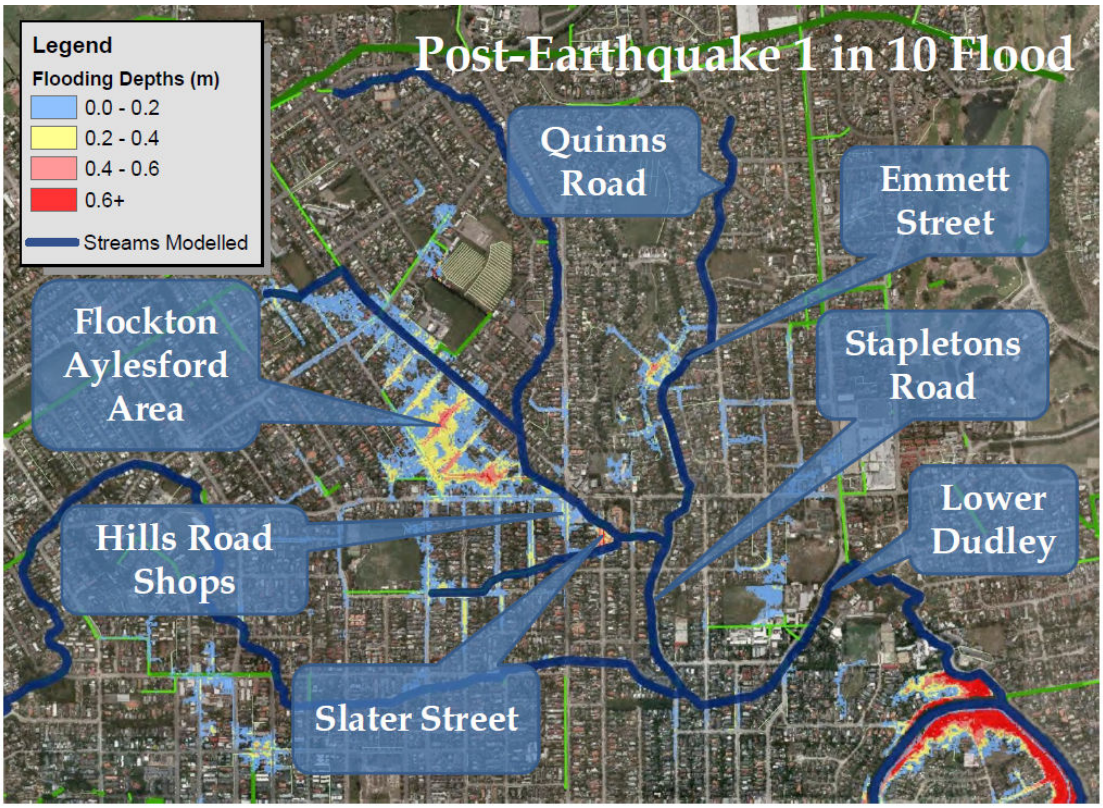


Figure 5 Post-earthquake 1 in 10 year flood extents (with key landmarks noted)

The calibrated modelling results were combined with an extensive floor level survey in the catchment to identify the number of floor levels at risk from flooding in both the pre- and post-earthquake catchment. Added to these were the Taskforce Level 1 properties where these were not identified by the modelling (Figure 6). This analysis quantifies the significant increase in the number of at-risk floor

levels due to the effects of the earthquakes for *both* the 10 year and 50 year average return interval events.

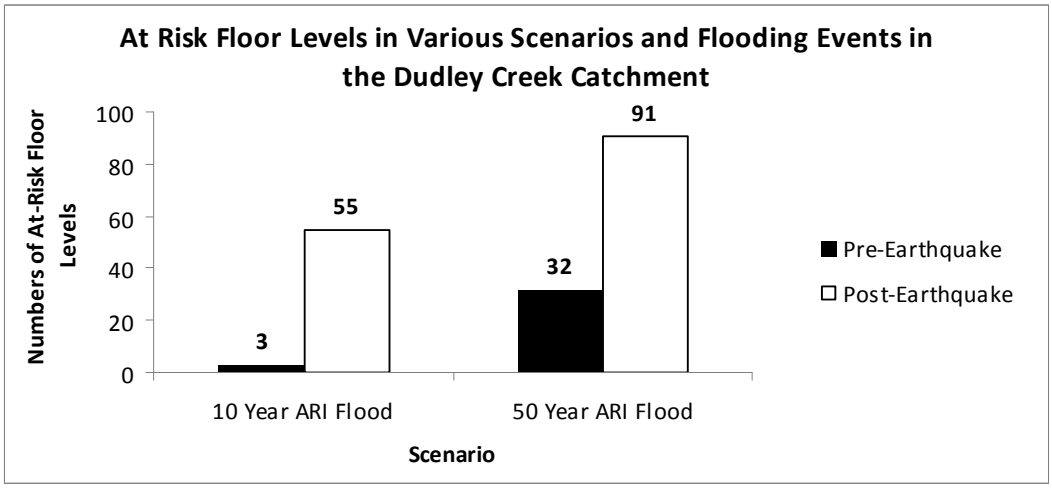


Figure 6 Houses at risk from above floor flooding pre- and post-earthquake

Note that the numbers in Figure 6 are based on both theoretical design storm events *and* the Taskforce numbers. Therefore the Taskforce Vulnerability Level 1 results (54 houses in Dudley Creek Catchment) are less than the numbers above.

In the Lower Heathcote investigations under the LDRP are continuing to assess earthquake effects. More data is needed, particularly on floor levels in the area. The initial indication is that the earthquakes have increased the depth and extent of flooding in the Lower Heathcote.

Other areas examined by the Taskforce do not have this level of detail available from the LDRP, but for each measure proposed by the Taskforce a clear earthquake effect was determined through site inspections and information from local residents. These effects include land subsidence, reduced capacity of waterways, and damaged infrastructure. The table below summarises the earthquake effects on land drainage in each priority area (Table 1).

Table 1 Earthquake effects on land drainage in each priority area

Dudley	
Waterway changes	Extensive bed heave, silt deposition and lateral spreading along Dudley Creek and its tributaries with a resultant loss in hydraulic capacity has occurred. Council have undertaken silt clearance works through the waterways in 2013 and 2014.
Land level changes	A large proportion of the catchment has subsided between 200 and 500 mm resulting in a net loss in grade across the reach.
Flood defence damage	There are flood defences in the Dudley Creek catchment that have been quantifiably affected by the earthquakes.
Infrastructure damage	Damage to culverts and failure of timber retaining structures has been observed across the lower catchment. Structural damage to culverts falls within the scope of SCIRT and remedial works to these and the piped network are proposed in the catchment.
Lower Avon	
Waterway changes	Bed heave has occurred within the Lower Avon reach. The local drainage network has suffered a reduction in capacity during peak river levels due to ground settlement. Moderate to severe lateral spread has occurred along the length of the Avon and within

	the Residential Red Zone and the Avon River banks suffered significant slumping as part of liquefaction and lateral spreading.
Land level changes	Land changes between 100m to -500m have been observed along the Avon with some localised movement of up to -1.0m. Residential land in the Brittans Drain area has settled by approximately 300 mm due to the earthquakes. This settlement is greater along areas immediately adjacent to Brittans Drain and in the Residential Red Zone with settlement in these locations of up to 1 m. The fall of the land however is relatively unchanged.
Flood defence damage	Temporary stopbanks were reconstructed along the river's edge. Each major earthquake event caused further damage and settlement to the stopbanks. These stopbanks continue to suffer from bank slumping and fill consolidation. This results in areas of the stopbanks being lower than the river flood level.
Infrastructure damage	The emergency response placement of the stopbanks has inadvertently covered some manholes and sumps causing local drainage issues. Ongoing maintenance difficulties are being experienced. SCIRT modelling investigations suggest that any post-earthquake reduction in service is predominantly due to damage to piped infrastructure rather than land settlement. Concept design of the stormwater system recommends repair of 8% of the pipes in the catchment and renewal of 32%.

Heathcote Valley

Waterway changes	Localised stop bank damage was observed at Clarendon Terrace. There are some informal 'tidebanks' on the Lower Heathcote which may have settled between 100-300mm. The initial tidebanks were designed to generally contain a 50 year event of 10.8 -10.9 m. Settlement may mean that tidebanks are now lower than design. A May 14 survey between Radley and Garlands identifies about 20% of the tide banks are up to ~200mm below 10.90m. SCIRT works and other contractors have caused isolated low points in the tidebanks due to construction activities. Flapgates may have rotated at the outlets and no longer close.
Land level changes	The only area of significant land change is along Truscotts Stream Branch timbered drain which has been shown to settle by 0.8 m to 0.9 m. The lower board level enabled the water to breach the timbering at this low point adjacent to Deavoll Place and flow across Truscotts Road and into Deavoll Place with the flood levels threatening houses in this area.

Upper Heathcote

Waterway changes	Localised bed heave is likely to have occurred. Site observations and conversations with property owners indicate that some areas have experienced lateral spread. Comments for residents suggest in some areas the bed of the river is now lower.
Land level changes	The CGD vertical and horizontal ground movement database indicates the area has generally settled 0.1 m to 0.3 m during earthquake events.
Infrastructure damage	The existing 225 mm internal diameter pipe was replaced with a 300 mm pipe outfall under a SCIRT work package on the Heathcote River.

Lower Heathcote

Waterway changes	Moderate to major lateral spread has been exhibited in around Hanson Park, Clarendon Terrace and downstream of Radley Street to Woolston Cut. An area downstream of Woolston Cut on the northern bank to the estuary has also suffered

	lateral spread. Settlement has resulted in reduced hydraulic capacity of drainage network around the Tennyson Street flooding area. The lower reaches of the Heathcote suffered raised bed level in the region of 400 mm and therefore has reduced the hydraulic gradient of the river resulting in a loss of capacity. Bed heave and increase sediment deposition has occurred between Aynsley Terrace and the Heathcote Tow Path. It has been estimated this change in sediment is 130,000 m^3 of deposited silt post-earthquake. Woolston Cut has risen up to 400 mm and therefore has reduced its hydraulic capacity. Liquefaction occurred at locations of the Lower Heathcote area which has contributed to significant volumes of material entering the Heathcote River.
Land level changes	Between Barrington Street and Opawa Road land changes post earthquake show a change on average drop of 0.1 to-0.2 m in ground level. Some localised areas have experienced drops of 0.4 m and 0.5 m. From Opawa Road to the estuary land levels have generally rose by 0.2 to 0.3 m. SCIRT GIS maps indicate that some properties along the banks of the Heathcote have slumped and therefore are more susceptible to flooding in peak events. There are also isolated areas of differential settlement in the Tennyson area. The area at the end of Tennyson Street and the rear of Somerfield Street has experience settlement of 0.2 to 0.30m. In addition local information indicates a spring appeared in a garage on Somerfield Street.
Flood defence damage	Localised stop bank damage was observed at Clarendon Terrace. There are some informal 'tidebanks' on the Lower Heathcote which may have settled between 100-300mm. The initial tidebanks were designed to generally contain a 50 year event of 10.8 -10.9 m. Settlement may mean that tidebanks are now lower than design. A May 14 survey between Radley and Garlands identifies about 20% of the tide banks are up to ~200mm below 10.90m. SCIRT works and other contractors have caused isolated low points in the tidebanks due to construction activities. Flapgates may have rotated at the outlets and no longer close. Woolston Cut has risen up to 400 mm and therefore has reduced its hydraulic capacity.
Infrastructure damage	SCIRT damage assessment maps indicate that there was considerable damage to pipes adjacent to the river. This includes damage to outfalls and flap gates. SCIRT works to be undertaken include repair of some damaged stormwater pipes in the area. Residents highlighted issues with sumps blocked with silt and other detritus post-earthquake on a regular basis. In other areas SCIRT condition assessment maps indicate non critical damage to the drainage network in other areas.
Southshore	
Waterway changes	Moderate to major lateral spread has been observed on the western side of Southshore.
Land level changes	Significant land changes have occurred post-earthquake. The eastern edge of Southshore has been shown to have risen by 0.4 to 1.0m. To the west of this and in the central section of Southshore a drop of 0.1 to 0.5 m has occurred. Drops of 1.0 to 1.5 m have occurred at the south-western area of the spit and in the area south of Bridge Street and around Owles Terrace.
Infrastructure	There is outfall damage at a number of locations south of Owles Terrace. The

damage	construction of the temporary stopbanks and subsequent earthquakes has further damaged the connecting pipes and outfalls. Minor damage has occurred to pipes around Kibblewhite Street where the stopbanks have been raised resulting in poor flood management protection of this area. All the major outfalls sustained damage on the western side of Southshore.
Sumner	
Waterway changes	The invert of the Colenso Street Sumner Main Drain (SMD) culvert has cracked and heaved along its length. The SMD bed has also heaved slightly in some locations. Sediment deposits in Sumner Stream /SMD along Wakefield Avenue and Paisley Street are possibly from unstable slopes within Red Zone and surrounding slopes in the rural zone.
Land level changes	The CGD vertical and horizontal ground movement database shows the difference between 2003 and June 2011 LiDAR data. This indicates that the flat land of Sumner has lifted near the Port Hills and dropped nearer to the coast. Some areas of Moncks Bay have uplifted by 0.5 m.
Infrastructure damage	Localised earthquake damage to pipe infrastructure occurred and is to be repaired under SCIRT projects #11055, #11108 and #11107. SCIRT project #11107 includes road reshaping in front of the properties identified as the most vulnerable from flooding by the Rifle Range Drain secondary flow path on Main Road. A pulled joint at the Rifle Range Drain outfall will also be repaired as part of this project.

1.3 Definition of 'regular post-earthquake flooding'

The Taskforce is concerned with 'regular' flooding, which means flooding like that which occurred in August 2012, June 2013, Easter 2014 and the evening of 29 April 2014. It is this level of flooding which is considered to have been most significantly worsened by the earthquakes and potentially able to be mitigated through short-term flood defences.

The Taskforce did not look into defence against more extreme flood events, such as that which occurred on 5 March 2014. In many parts of the city the associated flooding may have been worse than the 50 year flood event that the Building Act uses as a minimum design standard for flood protection of houses.

The Taskforce has not attempted to define the level of protection provided against a particular return period for any of the defence measures. This is common for long-term measures, but because the Taskforce was focused on short-term measures using recent events as benchmarks, it was not considered necessary. The events cited above had a range of return periods depending on where the rainfall was measured. However, it is considered that there have been enough post-earthquake flood events to provide sufficient variability in event size, effects and spatial distribution to allow for this approach to designing short-term measures.

2 Council policy and planning context

2.1 Strategic planning context

This report deals specifically and deliberately with short-term and 'immediate' flood defence options. In the context of the four R's approach (Civil Defence Emergency Management Act 2002) *risk reduction*, *readiness, response* and *recovery* – the options described in this report are primarily *risk reduction* and *readiness*. *Response* and *recovery* matters are being dealt by the civil defence and land drainage programmes within Council. It is widely accepted that a combination of the four R's delivers the most effective and efficient outcome in the long-term.

The Council is proposing to prepare a 'hazard strategy' in 2014/15. The strategy and its implementation will provide greater security to people from a wide range of hazards, including flooding, through the recovery period following the earthquakes and for the future development of Christchurch. The flood mitigation options given in this report will need to be considered by the Council within that broader context and integrated into the established stormwater management planning and operational floodplain management processes. The implementation of the temporary or short-term options identified in this report will be carefully considered by Council to ensure they align with longer-term and sustainable flood risk reduction options and take into account the impacts of climate change.

Community involvement in floodplain management planning will help to ensure that the flood hazard is assessed in an integrated way. A broad range of structural and non-structural mitigation measures would be considered and implemented to reduce flood risk. Historically the Council's emphasis has been on structural mitigation works, for example stopbanks and floodwalls. The focus has shifted to non-structural or 'soft(er)' mitigation measures such as planning controls, property acquisition, relocation, raising structures, flood proofing, insurance, bridge up-grades, natural environment restoration (e.g. wetlands), and emergency management response plans. This integrated catchment management approach aims to improve water quality and ecosystem health. This in turn supports broader recreation, heritage, landscape and cultural values.

The most successful *non-structural* mitigation measures are those that keep people, their structures and activities away from flood waters and help the community cope when flooding occurs. Land use measures influence the location of buildings and other structures – including district plan rules for floor levels, control of development in high risk areas, and information and advice to help people make their own decisions. The key benefit of non-structural mitigation measures and programmes is that they help establish partnerships across a broad range of individuals and organisations and often result in more acceptable cost-sharing arrangements.

It is likely that for some flood-prone parts of Christchurch the Council will need to prepare more detailed floodplain management plans. The approaches and processes used elsewhere in New Zealand are appropriate and relevant to addressing the flood risk in many parts of Christchurch. The Council's proposed 'hazard strategy' will provide further guidance on the need for and preparation of floodplain management plans.

2.2 Risk management

Risk management is an integral part of floodplain management planning. The Standard, *AS/NZS ISO 31000:2009 Risk Management - Principles and Guidelines,* is internationally recognised and provides a comprehensive approach for managing risk. In developing a 'hazard strategy' Council will promote and advocate the process given in the Standard to help achieve sustainable development in flood prone areas without imposing unacceptable constraints or costs on current or future generations.

Risk management involves three key steps - establish the context of the issue, identify and evaluate mitigation options and treat the risk. The context within which Council will consider the short-term options presented in this report 'now' and in the future will include:

- Avoiding the risk (e.g. land use controls to manage activities in high risk areas)

- Reducing the frequency of flooding (e.g. stopbanks and pumping)
- Reducing the consequences (e.g. planning and building controls to allow flood proofing of buildings, allow for relocatable buildings, and for retreat)
- Transferring the financing risk (e.g. through insurance, EQC and disaster relief funds)
- Accepting risk (e.g. recognising and addressing residual risk through emergency management response actions)

Council will evaluate the flood mitigation options on account of the level of risk reduction that can be achieved now and in the future together with the costs and benefits of risk reduction measures. Selection of the most appropriate options will involve balancing the costs of implementation against the short-term and long-term benefits derived from them. It will be appropriate for the Council to take an 'all-hazards' approach, that is, not only flooding will be considered in decisions on some mitigation options.

2.3 Statutory and non-statutory framework

Council has a wide range of natural hazard management related powers, functions, duties and responsibilities across many statutory and non-statutory documents. A review of the statutory and non-statutory policy framework for addressing flood risk across Christchurch has been completed by the joint Canterbury Earthquake Recovery Authority & Christchurch City Council flood Taskforce working group. The review provides the Council with useful context to prepare the hazard strategy and in doing so to explore further some of the suggested options in this report.

The implementation of some of the engineering options in this report would be achieved through exercising some of the powers that the Council has. Some of the powers have already been exercised in the immediate response to recent flood events, for example channel maintenance works.

Furthermore, the well-established and well-accepted floodplain management planning approach is reflected in various Council documents (some having specific recommendations adopted by Council) including the *Surface Water Strategy 2009*, integrated catchment management plans, the *Heathcote River Floodplain Management Strategy*, the *Avon River Floodplain Management Strategy*, and the *Waterways, Wetlands and Drainage Guide*. Of particular relevance for the Council when considering the flood mitigation options in this report are the multi-value approaches explicitly discussed in the *Surface Water Strategy 2009* and in the *Waterways, Wetlands and Drainage Guide*.

Overall, Council will make certain that 'policy' adopted already by Council and other guidance prepared by the Council will help direct the selection and implementation of flood mitigation options described in this report. In additional to existing Council documents, the Council's proposed 'hazard strategy' will provide additional direction for prioritising and implementing the flood risk reduction options.

The Council will also consider the flood mitigation options given in this report in the context of the Christchurch District Plan (currently under review) proposed natural hazard and related land use provisions.

3 Existing initiatives

The focus of the Taskforce is on short-term solutions to flooding resulting from the Canterbury earthquake sequence. Long-term flood mitigation measures are the focus of Council's normal operational and capital programme, as well as the focus of other initiatives described below.

3.1 Land Drainage Recovery Programme (LDRP)

The Land Drainage Recovery Programme was established by Council in 2012 to understand the consequences of the earthquakes on the land drainage network comprising of 79 km of rivers, 160 km of tributaries, 130 km of utility drainage channels and 790 km of piped stormwater network and structures.

From the initial investigations a prioritised programme of capital works or adaptive management approaches is to be developed in order to restore the flood impacts to at least pre-earthquake levels

A total of 63 separate projects were identified within the programme of works and work commenced on the highest priority catchments in the Dudley Creek, Wairarapa and Wai-iti Streams, well before the series of extreme rain events commenced in August 2012.

3.2 Stronger Christchurch Infrastructure Rebuild Team (SCIRT)

SCIRT's primary objective is to: "Return the Land Drainage Network to a condition that will facilitate the provision of Level of Service (LOS) that were provided prior to the 4 September 2010 earthquake". However SCIRT's scope is limited to public road and pipe drainage network and excludes open drains, rivers, stopbanks and private land or drainage infrastructure. In many cases, achieving the required LOS will only be achieved once other work outside SCIRT's scope has been completed by other agencies, such as Council through the LDRP.

Depending on the complexity of the catchments and extent of earthquake induced land damage, many of the catchments have been modelled for pre- and post-earthquake scenarios in order for SCIRT designers to understand optimal repairs or modifications to the drainage network are required to reinstate the desired LOS.

The Taskforce have engaged with SCIRT designers to assist in understanding some of the earthquake related drainage issues and what rebuild works are being undertaken by SCIRT.

Figure 7 Squire St from Aylesford St, June 2013

3.3 Alignment between SCIRT, NERP and LDRP

Council has requested an explanation of how the work that SCIRT is doing aligns with the;

(a) Natural Environment Recovery Programme (NERP), and
(b) The Land Drainage Recovery Programme.

The NERP contains seventeen projects, and several of these are connected to SCIRT work. The Land Drainage Recovery Programme is included within the NERP project "*Reduce flood risks and restore drainage capacity of waterways*". Further detail is provided below (Table 2):

Table 2 Alignment between SCIRT, NERP and LDRP

NERP Project	SCIRT connection
Reduce flood risks and restore drainage capacity of waterways Flood mitigation; stopbanks and other works; resilient sustainable infrastructure in rebuild Includes CCC LDRP	SCIRT's scope of work is outlined in the Infrastructure Recovery Technical Standards and Guidelines (IRTSG), which has been agreed and signed off by the three clients. SCIRT's responsibilities are focused on the repair and replacement of the damaged stormwater piped network. SCIRT is undertaking condition assessment of the underground piped system and is replacing / repairing pipes where they meet the threshold standards. The work schedules proposed are discussed with both the land drainage operational team and are checked against the known proposals within the Land Drainage Recovery Programme. In sensitive flood risk areas of the city, where SCIRT has undertaken assessment work and concept plans are developed, these are being held prior to final design and construction so that they can be integrated with any other known works being undertaken through other work programmes. For all works undertaken by the SCIRT rebuild team the "outfall" conditions and locations are fully discussed with key CCC staff to ensure that they are compatible with any wider land drainage improvements. However, it has become necessary to further optimise SCIRT repairs of stormwater infrastructure and the repair strategy has been amended in order to reduce the overall rebuild cost. This may impact on what is repaired by SCIRT.
Act on opportunities to reduce sewage overflows and their effects Reduce the incidence and effects of sewage overflows During rebuild, improve wastewater infrastructure to reduce/avoid wet weather sewage overflows directly to waterways; minimise their effect.	Repairs to the wastewater network will progressively reduce the frequency of wastewater overflows to the rivers in the long term by restoring the integrity of the network and reducing inflow and infiltration. Opportunities for improvement of Infrastructure are discussed with key CCC staff to confirm viability of options and of the availability of additional funding. SCIRT delivery teams are industry leaders in minimising risks of wastewater overflows during construction. A best practise guideline capturing the learnings has been shared with industry and recently won a Green Ribbon award.

NERP Project	SCIRT connection
Act on opportunities for stormwater treatment and improving the water quality and ecosystem health of waterways Stormwater treatment systems; stream and river restoration; riparian zones; establishment of constructed wetlands Use Low Impact Urban Design and Development/ stormwater treatment systems/ wetlands to attenuate stormwater flows, reduce sediment, and improve quality of stormwater into waterways. During rebuilding consider changing the form of waterways to enhance stream ecology. Plant riverbanks to provide food sources, habitat and shade.	To date SCIRT have undertaken land drainage designs in accordance with the IRTSG which provides for returning the land drainage piped network to a condition that will facilitate the provision of levels of service to a similar level to that which was provided prior to the 4 September 2010 earthquake. As the SCIRT network repairs have generally been proceeding well ahead of the Land Drainage Recovery Programme, the SCIRT work has assumed that the land drainage network not within SCIRT's scope will be returned to pre-earthquake boundary conditions or that any new boundary conditions have been agreed and taken into account. Designs have been approved by CCC and as necessary presented to the Land Drainage Operations Manager for feedback, with amendments made where required. On occasions SCIRT has handed over hydraulic modelling undertaken for its work to be further developed for the Land Drainage Recovery Programme. Construction techniques and mitigation measures adopted by the delivery teams are planned to minimise adverse discharges to the environment and are subject to regular audits.
Protect groundwater and springs Land use controls to protect groundwater; springs, daylighting streams Ensure land use controls over the unconfined aquifer. Investigate potential effects of foundation systems on groundwater. Encourage the retention of natural springs and daylighting streams.	SCIRT works under a land use consent from Environment Canterbury which contains conditions for the protection of springs and groundwater quality.
Manage earthquake waste Waste monitoring; waste disposal; increased recycling; controlling illegal dumping; waste management plans Improve monitoring and tracking of earthquake-related waste; enforce and manage aftercare of storage, sorting and disposal sites. Maximise recycling at or near source. Reduce illegal dumping by increasing compliance monitoring and enforcement. Prepare waste management plans for future disasters.	Approximately 95% of waste generated on SCIRT construction sites is diverted from landfill. SCIRT delivery teams have demonstrated that they meet minimum criteria for waste management, including waste measurement and ensuring waste is taken to approved facilities. Waste minimisation ideas are acknowledged and shared through the environmental initiatives KPI that have been developed by SCIRT.

NERP Project	SCIRT connection
Manage contaminated sites Identification of Hazardous Activities and Industries List (HAIL) sites; comply with National Environmental Standard (NES) for contaminated land Undertake a programme of HAIL site identification. Inform and educate on the requirement to comply with the NES triggered by land use changes.	SCIRT works under a land use consent which sets out the procedures for working on and adjacent to potentially contaminated land, and regularly provide the results of all testing and investigation of contaminated land to Environment Canterbury and Christchurch City Council.

3.4 Flood Management Steering Group

The Flood Management Steering Group was established following the March 2014 flooding. While Council has responsibility for flood management it is working with other agencies to ensure a collaborative cross-agency team approach to flood management issues in Christchurch following the Canterbury earthquakes. At present the Steering Group consists of Council, CERA, ECan, the Department of the Prime Minister and Cabinet, and the Ministry of Business, Innovation and Employment.

The Steering Group has a joint work plan, which is focused on medium to long term flood mitigation options and includes five key components:

1. Ensuring agencies have a robust and common information base
2. Defining the nature and extent of the issues
3. Determining policy objectives and establishing criteria for analysing options
4. Identification and assessment of options
5. Ongoing community engagement and communication

The main issues being considered by the Steering Group are:

1. The nature and extent of the flood risk for different parts of the city – in particular, how flood risk has changed as a result of the earthquakes;
2. The level of flood protection required, and responsibilities for ensuring that this protection is provided;
3. The extent of the Earthquake Commission's liability for increased flood vulnerability and whether this can lawfully be addressed through an area-wide solution rather than individual settlement payments;
4. The objectives to be achieved in addressing flood management issues, and criteria for assessing options;
5. The range of options available to address flood management issues – including short-term and long-term options, and the costs, benefits and risks associated with each;
6. Legal implications – including the adequacy of existing regulatory tools to support desired options, any justifiable need to make use of the powers of the Canterbury Earthquake Recovery Act 2011, and potential challenges from individual property owners if area-wide solutions are pursued;
7. Financial implications and funding options; and
8. The expectations and preferences of affected property owners, and how best to engage them in these processes.

Recent work by the Steering group has continued to progress the joint work plan, completing many of the tasks required to develop a robust and common information base. Information has been gathered to improve the understanding of:

- the impact of climate change on flood risk in the longer term
- approaches taken to addressing flood risk management nationally and internationally
- previous funding for flood mitigation works through the Ministry of Civil Defence and Emergency Management
- the impacts of flooding on residents, and existing sources of assistance
- the position of, and issues for, the Earthquake Commission, insurers, and banks.

3.5 Earthquake Commission (EQC)

EQC provided the following advice to the Taskforce:

1. Increased Flooding Vulnerability (IFV) is a type of land damage covered by EQC. In some parts of Christchurch the earthquakes caused changes to residential land that mean some houses are now at risk of flooding where previously they were not and some are now at risk of flooding to a greater extent.

2. EQC has now completed its flood modelling programme in Christchurch city to identify which properties may have IFV. EQC has written to approximately 9000 customers to advise them that they have potentially suffered IFV damage and to explain the next steps in the process. The engineering work is now underway to validate the modelling results through review and site visits. Once the engineering work for a property has been completed then then independent valuers will visit the property to confirm the damage has resulted in a loss of value to the property and to collect information required to determine the settlement amount.

3. Where possible, EQC will settle a land claim by providing a cash payment based on the amount it would cost to repair or reinstate the land. However, for properties vulnerable to flooding it will often not be possible to identify a repair to the land which is feasible or consentable. Therefore, EQC may settle by Diminution of Value - the long term loss of value the property has suffered as a result of the increased vulnerability it now has to flooding.

4. EQC has also been working with Council to identify whether there are area-wide offsite flood mitigation works that could be undertaken to remove the flooding vulnerability or at least reduce it to pre-quake levels. Where these schemes can be identified, costed and completed in a timely manner then EQC is open to contributing as a way of resolving some IFV claims.

5. EQC has sought declarations from the High Court on questions relating to EQC's coverage of properties now at greater risk of flood damage due to the Canterbury earthquakes. A hearing will be held in October.

3.6 Declaratory judgment on flood prone properties

The Earthquake Commission has sought declarations from the High Court on questions relating to EQC's coverage of properties now at greater risk of flood damage due to the Canterbury earthquakes.

The particular issues that EQC has asked the Court to consider are:

- To confirm EQC's determination that Increased Flooding Vulnerability is a form of land damage covered by the EQC Act.
- Whether a settlement based on the loss of market value that the property has suffered due to the IFV damage is permitted under the EQC Act. This method of settlement has been publicly referred to as Diminution of Value (DOV).
- To confirm that the policies that EQC has adopted, based on advice from its expert engineering and valuation advisers, to determine IFV damage and to calculate settlement are appropriate.

Consideration by the Court of these issues will allow customers to have confidence in the settlement they receive from EQC. To ensure that a broad range of arguments were put to the Court, EQC invited the Insurance Council of New Zealand to join in the proceedings.

The Council has joined the judgement and wants the Court to declare that not just increased flooding vulnerability of land but also increased flooding vulnerability of buildings is damage that is covered by EQC. The Council is querying whether the EQC policy that EQC is asking the Court to approve is an appropriate, reasonable or rational basis for settling claims and that it doesn't address changes to buildings.

Figure 8 Eastern Terrace on the Heathcote River, 29 April 2014

4 Social impact

4.1 Introduction

The flooding events over the last three years have impacted on people's health and wellbeing, their ability to cope with uncertainty and change, and their ability to cope financially. In order to address those most impacted by this the Taskforce investigated the social impacts in the worst affected areas of Christchurch with the most vulnerable people and properties.

This section of the report discusses the findings from the engagement with the communities on these issues.

4.2 Assessment of vulnerability

Vulnerability is defined in two complementary ways; the vulnerability of the house to flooding and the vulnerability of the occupants of the house. The first dimension is those houses and their properties that are prone to flood risk. The health and habitability of houses is the first consideration when it comes to addressing flood risk.

A home affected by the flooding events of the past six months was deemed habitable if the living conditions inside the home are similar to the living conditions in other homes in Christchurch that have not been flooded. It must be able to be occupied to a satisfactory level of health for its occupants. For example, compared to other similar homes in Christchurch, the home is warm and dry, it can be heated, it does not contain mould in the dry areas of the home and it does not increase the risk of respiratory illness and other illnesses worsened by mould, damp and cold.

The second dimension of vulnerability relates to the occupants of those houses and their ability to cope with flooding and the ongoing effects of flooding. The most vulnerable will need to be prioritised when implementing individual property solutions. The most vulnerable are defined as: people with mobility needs, people with mental and physical health needs; families with young children and people in uninhabitable homes.

Conceiving of vulnerability in terms of the property and the household recognises that there is not a one size fits all approach or solution, especially when it comes to short term solutions.

4.3 Flockton case study

The Taskforce gathered quantitative and qualitative data from residents in all priority areas about the effects of flooding on their community. The community in the Flockton area was prioritised due to the magnitude of the flooding and community engagement there consisted of:

- A face to face survey of approximately 150 households in the Flockton area that were known to have been flooded in the March 2014 event.
- The survey was distributed more widely and a number of residents in the wider Flockton area and surrounding neighbourhoods reported flooding.
- An information drop in centre for residents, elected members and other interested parties to ask questions and speak to Council staff face to face. The survey was available and many attendees filled out the survey at the drop in centre.
- Two focus group meetings for elected members, key stakeholders and residents in the Flockton area.
- Community engagement undertaken with residents, businesses and key stakeholders in the Flockton area on Saturday 3 May 2014.

The Taskforce received over 120 completed surveys, over 50 people attended the focus groups meetings and a large number of people dropped into the information drop in centre.

The Flockton Social Impact Assessment (SIA) looked at the impacts of the flooding events on the community in Flockton as well as the impacts of the proposed short term engineering and non-engineering measures. Information on community issues and concerns was drawn from a number of sources, including:

- The Flockton Residents' Group survey completed by 59 people; and
- Previous community meetings and communications with residents and key stakeholders in the Flockton area.

A quantitative survey of Flockton residents found that:

- 95% of respondents agree or strongly agree that flooding in the Flockton area will have an effect on property values.
- 92% of respondents agree or strongly agree that flooding affects their morale.
- 91% of respondents agree or strongly agree that they are worried about the effects of future flood events on the health and wellbeing of the occupants of the house.
- 83% of respondents agree or strongly agree that apart from flooding, they like the area and they want to stay.

This indicated that residents in the Flockton area have significant concerns around property values, morale and health and wellbeing. Overall, the results of the feedback from the Flockton community clearly demonstrate that the wider flooding issues have significant impacts on:

- Physical health
- Personal wellbeing
- Financial wellbeing
- Community wellbeing

Despite those concerns most residents like the area and want to stay, although there is a core group of residents who would prefer a buy out and want to leave the area. Coupled with the findings from the focus groups, people's willingness to stay is dependent on their level of confidence that the Council and other agencies can solve the flooding issues in the area.

This data informed the Flockton *Social Assessment Report* and the key themes that emerged from the data are:

- Living in warm, dry, healthy homes is a priority for physical health and for personal wellbeing
- There are concerns around physical health including: gastric health, respiratory health, contaminated land and the health of children
- There is a reported increase in stress, depression, feelings of hopelessness, frustration, anger and powerlessness. These feelings are partly because of a perceived lack of coordination between the agencies, a lack of communication from the agencies and lack of urgency from the agencies. These feelings are also because of uncertainty about the future, financial worries, and living in cold, damp, unhealthy homes
- Financial concerns including increased insurance excess, loss of equity in homes, increased financial obligations such as having to service a mortgage and pay rent, increased electricity and heating costs, impacts on businesses (loss of revenue) and forced annual leave
- Potential loss of community and/or fragmented communities and a loss of amenities

4.4 Community engagement

Once the process was developed with Flockton, community engagement took place around the city in all the flood-affected priority areas. This took the form of community meetings, surveys, and discussions in the field with engineers visiting flood affected areas.

4.4.1 Community meetings

A series of community meetings began on 21 May 2014 in the areas affected regularly by flooding. Residents were invited along to discuss flooding issues that affect their community. These meetings were attended by engineers from the Taskforce, Council staff and representatives from other key agencies. The purpose of the meetings was to present information and answer questions about the recent flooding events, interim Taskforce findings and the proposed flood mitigation work. The details of these meetings are shown below.

Table 3 Taskforce Public Meetings

Location	Time
Area: Little River Venue: Little River Community Centre	Date: Wednesday 21 May 2014 Time: 6pm–8.30pm
Area: Upper and Lower Heathcote Venue: Somerfield School Hall, 42 Studholme Street, Somerfield	Date: Tuesday 27 May 2014 Time: 7pm–9pm
Area: Sumner Venue: Old School Hall, 20 Wiggins Street, Sumner	Date: Thursday 29 May 2014 Time: 7pm–9pm
Area: Flockton/Dudley Creek Venue: Edgeware Bowling Club, 6 Forfar Street, Edgeware	Date: Tuesday 3 June 2014 Time: 7pm–9pm
Area: Lyttelton Venue: The Top Club, Dublin Street, Lyttelton	Date: Wednesday 4 June 2014 Time: 6pm–8pm
Area: New Brighton and Southshore Venue: South Brighton Community Centre, 74 Beatty Street, South New Brighton	Date: Thursday 5 June 2014 Time: 7pm–9pm
Area: Lower Avon and CBD Venue: Wainoni Methodist Church, 878 Avonside Drive, Wainoni	Date: Wednesday 11 June 2014 Time: 7pm–9pm
Area: Heathcote Valley Venue: St Mary's Church Hall, Corner of Martindales and Truscotts Road, Heathcote	Date: Thursday 12 June 2014 Time: 7pm–9pm

Questions and answers were recorded at each meeting and then published to Council's website.

4.4.2 Survey

Following the publication of the Final Draft report in May, a survey was developed to help verify the preliminary data and any new data reported by residents after the publication of that report.

The survey collected information on the number of times an address has flooded above floor level, below floor level and the number of times house access has been affected by flooding. It also

collected information on household occupants. This data allowed the Taskforce to assign a vulnerability level to each property. Gathering residents contact details also allows Council to stay in touch with those affected if necessary.

The Council assigned three call centre staff to phone residents and obtain the required information. Council has now collected over 330 contacts (calls, e-mails, face-to-face meetings, and information from existing databases) from people expressing concern about flooding. Over 600 residents have been talked through the survey either at first point of contact or during a call back. This data has been processed to establish potential vulnerability and cross-referenced against field investigations. A total of 2,578 properties have been validated for flooding vulnerability by the Taskforce. There remain 49 properties that have not been validated as the results arrived too late to be fully assessed by the Taskforce.

4.4.3 Analysis

The Taskforce reviewed the questions asked and comments made at the community meetings, as well as the questions and comments made from phone calls and emails after the community meetings. Initial findings indicate that a number of the issues, concerns, preferences and social impacts identified in the Flockton area can be translated to other areas of the city. Some issues and concerns will be particular to each area given that they all have a unique geographic and community context and the flood related issues and potential solutions/options will be different. Some of the common recurring themes that emerged include:

- Uncertainty with timing of house repairs and the nature of these repairs
- Falling property values
- Health concerns with damp, mouldy houses
- The time it may take to remedy or reduce flooding and uncertainty of what to do in the meantime
- Insurance money running out and financial worries
- For the most affected residents, a one-on-one meeting to discuss their situation was the preferred method of contact, and many one-on-one meetings were organised

Overall, people's willingness to repair their homes and replace their belongings is dependent on their level of confidence that the Council and other agencies can remedy the flooding issues in their area. Further, prolonged periods of uncertainty are stressful both financially and psychologically for people.

This analysis work is ongoing and will further inform Council's and other agencies' psychosocial response to flood-affected households and prioritising the most affected areas and people. It may also help in prioritising physical works.

4.5 Social impacts of proposed short term flood mitigation measures

Two categories of short term temporary measures were considered: engineering measures and non-engineering measures. For Flockton, residents were asked their opinions on the proposed temporary flood defence measures. Below is a summary of people's responses to the acceptability of those options:

- Pumping in the local area emerged as the most popular temporary flood measure among respondents with 70% rating it as good or very good
- House lifting was the second most popular with 53% rating it as good or very good
- Sandbagging was the least popular option with 61% of respondents rating it as poor or very poor

Coupled with the findings from the focus groups, people in the Flockton area prefer solutions that provide for the whole area over options that only solve flooding in individual homes/properties.

The short term engineering measures will have varying degrees of impact on people and property. The impacts are shown in Table 4 below:

Table 4 Impacts and Mitigations of Short Term Engineering Measures

Option	Impacts	Mitigations
Local area schemes e.g. localised pumping, bunding	Positive • Gets rid of wider flooding problems • Reduces contamination risk • Improves area accessibility • Time taken to implement (pumping) • Includes external buildings (sheds, garages, sleep outs) Negative • Noise (pumping) • Area disruption (bunding) • Physical health (inhabited property) • Mental health (element of uncertainty) • Time taken to implement (bunding, regrading) • Vacant properties (upkeep, community safety)	• Property maintenance • Welfare info and communications and awareness (e.g. health issues) • Community development projects working with Neighbourhood Support and Neighbourhood Watch. • Continue/target insulation programmes • Continue winter make it right
House defence e.g. house raising, house wrapping, bunding,	**Positive** • Tailored property options • Possible long term benefits (e.g. house raising) **Negative** • Time taken to implement • Vacant properties (upkeep, community safety • Physical health (Inhabited property) • Reduced accessibility • Mental health (element of uncertainty) • Homes already damaged	• Welfare info and communications and awareness (e.g. health issues) • Community development projects working with Neighbourhood Support and Neighbourhood Watch. • Continue/target insulation programmes • Continue winter make it right • Proactive/Reactive • One point of contact • Ongoing dialogue between sectors

Given the impacts outlined above, non-engineering measures may be required to be implemented by agencies or individuals for the following reasons:

- The engineering measures may not be operational immediately and non-engineering measures may be needed in the immediate term to address ongoing flood risk and the potential impacts on people and the houses they inhabit
- Households may need to move out of their homes in the short term while an engineering measure is being implemented e.g. house raising
- Households may need to move out of their homes in the long term until a permanent solution is implemented
- Households may need to move out of their homes permanently if long term measures are unlikely to prevent the house flooding in a 50 year flood event

A number non-engineering measures were evaluated for agencies and individuals to consider:

- Buy out or buy back
- Temporary village
- Agency finds and pays

- Resident finds and pays
- Emergency accommodation

The short term non engineering measures will also have varying degrees of impact on people and property. The impacts are shown in Table 5 below.

Table 5 Impacts and Mitigations of Short Term Non-Engineering Measures

Option	Impacts	Mitigations
Buy Back	Positive • Housing stress relief (financial and wellbeing) Negative • Perceived inequity • Vacant properties (upkeep, community safety • Refusal to take offer • Disconnection from community • Disconnection from support structures	• Property maintenance and upkeep measures • Community development projects working with Neighbourhood Support and Neighbourhood Watch. • Welfare info and communications and awareness (e.g. health issues) • Single points of contact • Community group briefings • Community development projects working with Neighbourhood Support and Neighbourhood Watch.
Village type complex	Positive • Housing stress relief (financial and wellbeing) • Removes house finding stress Negative • Perceived inequity • Time taken to implement • Vacant properties (upkeep, community safety) • Refusal to take offer • Disconnection from community • Disconnection from support structures	
Agency finds and pays		
Resident finds and agency pays	Positive • Housing stress relief (financial and wellbeing) • Empowering individuals who may wish to live closer to friends, families, schools. Negative • Perceived inequity • Overwhelmed rental market • Vacant properties (upkeep, community safety) • Refusal to take offer • Disconnection from community • Disconnection from support structures	• Proactive communication from the Council and other agencies. • Utilise Council housing, Housing Entity/HNZC • School and health agency briefings and involvement.

4.6 Resident preferences

Preferences expressed by residents were a mix of both short term local area and house defence options implemented on a case by case basis. Engineering options that provide flood defence for the whole area are preferred over options that only provide defence in or around the house. Flood defence around the home or property does not always solve the wider accessibility issues such as getting to and from work, getting children to and from school and being able to move around in the area. Further, flood defence around the home or property does not stop wastewater contaminating stormwater and contaminating properties with subsequent health concerns.

Preferences for non-engineering options include:

- Temporary relocation and a buy back option thereafter (especially for older residents, rental properties, 'forced' returns, financial and/or health duress)
- 'Repair once' insurance approach once long term solutions put in place.

There was general agreement that a suite of measures would be needed to provide confidence in the flood mitigation solutions and the future of the area.

4.7 Options for temporary mitigation of social impact

The measures below are options that could be employed if needed. They are dependent on what short- or long-term solutions are decided upon. They are also most likely to be implemented by individuals or agencies other than the Council. Council's role may be limited to informing residents of agencies working in this area.

4.7.1 Improving education and awareness

A key part of mitigating the social impacts of flooding is improving access to information and raising awareness. The Taskforce has begun this work through public meetings, newsletters, FAQs, an information website etc. More recommendations are given in Section 17.

4.7.2 Buy back

The worst affected properties or properties required to undertake flood protection works could be identified and offered a 'buy back' option. This option would be voluntary and could represent a temporary or permanent retreat. .

This option is only likely where long-term options and solutions are being considered as part of a comprehensive floodplain management plan. It is unlikely to be implemented as a result of any of the Taskforce recommendations.

4.7.3 Temporary accommodation

Residents impacted by the flooding are able to apply for temporary accommodation assistance through the Canterbury Earthquakes Temporary Accommodation Service.

Where the Council is undertaking major engineering works within a catchment and requires unfettered access temporary accommodation could be offered for property owners using the "agency finds, agency pays" or the "resident finds, agency pays" options. These options could be in place for up to three years while a permanent solution is implemented.

4.8 Engagement with other agencies

4.8.1 Psychosocial Subcommittee: An Interagency Approach

The Council is working with the Ministry of Social Development (specifically the Earthquake Support Coordination Service), the Canterbury District Health Board, the Ministry of Education, CERA and

other non-government organisations who are members of the Psychosocial Subcommittee. The Psychosocial Subcommittee was set up by CERA[2].

In particular, the Council presented the work of the Taskforce to the Psychosocial Subcommittee on Friday 13 June 2014. The presentation included information on:

- The number of houses made more vulnerable to flooding as a result of the earthquakes,
- The number of vulnerable householders in those houses[3], and
- Council's initial findings on the impacts of flooding on people's health and wellbeing outlined in the Social Assessment Report.

The Council organised a follow up meeting on 25 June 2014 for Psychosocial Subcommittee members, the Council's Strengthening Communities staff and others interested in developing a joined up psychosocial response for those affected by flooding. Meetings will be ongoing.

4.8.2 Ministry of Education

The Council contacted the Ministry of Education (MoE) (19 June 2016) to understand their policies in relation to flooding. The purpose was to understand how the Ministry of Education responds to flooding events to ensure the health, wellbeing and safety of school children. The Council asked the following questions with the Ministry's response below:

How does MoE ensure consistency across schools during flood events?

"The Ministry has operating policies for an emergency which changes the inhabitation of schools for learners. Each type of emergency, flooding for example, can be escalated or reduced in response as required, however the action is the same for each. The Initial Task and Responsibility is the requirement of the Ministry of Education and that is done at either Regional level or National level or both. This decision is made at National office and implemented in the Regional office as required. The Ministry has a responsibility to inform the Minister's office. The Key Priorities of the Ministry of Education are written in Section 58 of the Civil Defence and Emergency Management Act 2002 and require it to "have an obligation to ensure it is able to function to the fullest extent possible during and after an emergency".

The Ministry also provides schools and ECE services with planning and emergency response resources and tools that they may use to effectively manage emergencies and traumatic incidents."

How does the MoE assure the community that school policies in relation to responses to flooding are consistent?

"School Boards of Trustees are responsible for the health and safety of students and staff and therefore community assurance that their policies relating to emergency responses are effective is also the BOT responsibility. The Ministry's interest is in the schools applying consistent and robust policies.

---

[2] Community groups and organisations that are actively part of the Sub Committee include: Christchurch City Council; He Oranga Pounamu; Selwyn District Council; Waimakariri District Council; Mental Health Education Resource Centre; Red Cross; Mental Health Services - CDHB; Planning and Funding - CDHB; Ministry of Health; Psychology Department - University of Canterbury; University of Otago; Ministry of Education; Relationships Aotearoa; Te Puni Kōkiri, Ministry of Civil Defence and Emergency Management; Inter-Church Forum Representative (Christian churches across greater Christchurch); Department of Internal Affairs; PORT Representative - Public Sector Organisational Resilience Team; Department of Child, Youth and Family, MSD; Family and Community Services, MSD; Earthquake Support Coordination Service Governance Representative; Earthquake Commission; NGO Sector Delegate & Pan-NGO Sector Delegate (One Voice Te Reo Kotahi, Social Service Providers of Aotearoa, Council of Social Services, Older Person's Network, Young Persons Network); Ministry of Pacific Island Affairs; All Right? Campaign Representative; Mental Health Foundation; Health Protection Agency; CERA - Canterbury Earthquake Recovery Association; Community and Public Health – CDHB. Taken from http://cera.govt.nz/recovery-strategy/social/community-in-mind#footnote.

[3] Further analysis is required on the vulnerability of the householders to understand their needs and the magnitude of the problem as well as to determine the social supports required to address their needs.

School policies are also considered as part of the review process which is undertaken by the Education Review Office."

How are school policies monitored for flooding and other events which impact communities?

"Ministry of Education staff are available to help ECE services and schools formulate and evaluate their policies, procedures and practices for use in emergency situations."

On which websites is the information about the MoE and schools responses to flooding available?

"A number of references can be found on the Ministry of Education website -www.minedu.govt.nz - including the Ministry's guide to managing emergencies and traumatic incidents - http://www.minedu.govt.nz/~/media/MinEdu/Files/EducationSectors/PrimarySecondary/EmergencyManagement/TheGuideSm.pdf

Schools may also use their websites to communicate with their community."

4.8.3 Canterbury Earthquake Temporary Accommodation Service

The Council has also been working with the Canterbury Earthquake Temporary Accommodation Service (CETAS) to determine:

- The best practice process required to provide financial support and accommodation to families requiring help.
- Clarifying CETAS policy, criteria and the resource required to provide support to flood-affected residents where flooding is earthquake related.

One outcome of this was that the Honourable Gerry Brownlee, the Minister for Canterbury Earthquake Recovery, and Honourable Paula Bennett, Minister for Social Development announced on 25 June 2014 that Canterbury residents impacted by earthquake related flooding are eligible to apply for Temporary Accommodation Assistance (TAA) programme which is administered by CETAS.

5 Wastewater overflows

Wastewater overflows can contaminate flood waters and this poses a public health risk. Overflows can occur via formal overflow structures designed to prevent wastewater flooding, or informally through manhole covers or private gully traps when the network surcharges (fills and becomes pressurised, Figure 9). The network surcharges due to rainwater finding its way into the wastewater network, significantly increasing the network flow. The Canterbury earthquake sequence has reduced network capacity and increased the volume and frequency of overflows.

Typically significant surface flooding is contaminated and the problem is not easily resolved, particularly when there are heavy storms. Even if wastewater overflows could be eliminated, the flood waters would still be a health risk due to E-coli bacteria from various sources. Appendix C contains further details on the wastewater system and flooding effects.

The Council actively manages wastewater overflows and has a good response procedure and reducing wastewater overflows is a focus of Council's long-term physical works programme.

There are some short term measures that could reduce the distress of the most vulnerable residents such as sealing of vents and decontamination after flooding. These are reported in the key findings and the Taskforce has provided to Council a proposed project outline for a pilot project to reduce wastewater overflows.

Figure 9 Wastewater overflow during a storm

6 Impacts of upstream development

Council resolution 5.4.8 required the Taskforce to 'Assess upstream developments for their contribution to flooding and whether mitigation requirements are being fully implemented.'

This arose because a number of people within the community have expressed a concern about upstream developments worsening the flood risk for people and properties lower down in the catchment. This section investigates the impacts of upstream developments on flooding.

The Council takes a carefully considered and pro-active approach to stormwater management across the city including:

- Policy framework of the surface water strategy
- Integrated catchment management through stormwater management plans
- Consenting and compliance monitoring of new subdivisions and City Council stormwater systems

6.1 Policy framework – Surface Water Strategy 2009 – 2039

Surface water is defined to include stormwater (including below ground pipes), springs, rivers, streams, lakes and associated wetlands. It includes all natural, artificial and ephemeral waterways and excludes groundwater and the sea.

The strategy articulates a number of goals:

- Improve water quality
- **Reduce adverse effects of flooding**
- Improve ecosystem health
- Protect and restore Ngai Tahu values
- Support recreation
- Protect heritage values
- Protect and enhance landscape values
- Support community involvement

Focusing on the goal ***reduce adverse effects of flooding*** the strategy notes that the city is naturally flood prone, much of it being drained wetland and flood plain. Good drainage and management of river flows is necessary to reduce the risk of flooding.

The objectives with respect to managing the flood risk are to:

- Maintain flood storage and flow capacity of ponding areas, wetlands and floodplains that remain largely undeveloped
- Limit further development in high flood risk areas
- Limit further development and mitigate the effects of flooding in moderate risk areas
- Manage the effects of development to avoid an increased flood risk on public and private land downstream

Land use activities are controlled through the City Plan. The Flood Management Areas limit development in ponding areas, require increased minimum floor levels for building protection, and assess the effects (and require mitigation) for displacement of floodwaters.

6.1.1 The challenge of urban intensification

When land is developed the vegetation that intercepts and slows rainfall run-off is removed. Grading flattens the terrains and fills natural depressions that would otherwise provide temporary storage. Topsoil and humus may be removed and the subsoil compacted. Buildings, carparks and other impervious surfaces increase stormwater run-off. Even without intensification property improvements such as patios, paving and driveways create additional demand for stormwater infrastructure.

6.1.2 Policy response

In urban intensification areas:

- Maintain existing stormwater infrastructure
- Implement multi-value stormwater management as opportunities arise
- Encourage on-site stormwater management where possible
- Promote the maximisation of pervious surfaces in developments and public spaces

In greenfield areas:

- Implement multi-value stormwater management
- Ensure the design of subdivisions minimises their impact on surface water

Multi-value approaches, such as low impact urban drainage design (LIUDD) principles, aim to use natural processes to provide stormwater solutions – adding value to urban environment by enhancing habitat, biodiversity, landscaping, amenity, recreational opportunities and cultural identity.

6.2 Stormwater management plans

The primary catchment management tool in Christchurch is the stormwater management plan (SMP). Two plans are currently active; those for the South West Area and Styx River. Other parts of the city have plans in development or are programmed for consideration.

6.3 South West Area Stormwater Management Plan

The SMP for the South West area was developed in 2009 and a stormwater discharge consent for the catchment granted from the Regional Council in 2012.

The overall objective of the SMP is to reduce flood levels in the Heathcote River to pre-1991 flood levels and to improve water quality, in keeping with the waterways and wetlands six values approach (ecology, landscape, drainage, culture, heritage and recreation). Stormwater engineering works associated with new developments will be required to reduce the stormwater run-off compared to pre-development conditions.

The blueprint specimen design for the South West area sets out the proposed stormwater network including:

- Pipes, swales and drains
- Streams and rivers
- Ponds and basins for infiltration to ground, detention and treatment
- Wetland areas.

The South West network (Figure 10) will be developed progressively over the next twenty to thirty years through a combination of Council initiated works and facilities built as part of private developments. The stormwater network in these greenfield areas is funded through a combination of private funding, developer contributions and rates.

The stormwater basins are generally designed on the basis of "Full Flood Attenuation" which means to capture the runoff from a 2% annual exceedance probability (50-year) storm event and either dispose of it to ground soakage or discharge it slowly to the network over a minimum of 96 hours. This typically results in reduced runoff from most storm events up to the 2% AEP return period over the pre-developed condition. The South West Area Stormwater Management Plan also has a component of retro-fit mitigation for many existing older development areas.

6.3.1 Wigram Skies

The stormwater run-off from Wigram Skies, along with a large catchment of existing upstream development is collected and treated through a combination of the Awatea Road, Wigram Aerodrome and Wigram detention basins. The land at Awatea Road was bought by Council and the stormwater infiltration and detention basins were built in conjunction with Ngai Tahu. The basins service Wigram Skies and some 400 hectares of existing residential development. The run-off from this catchment previously ran directly into the headwaters of the Heathcote River. With the construction of the stormwater basins, the discharge into the Heathcote headwaters from this catchment has been reduced approximately six fold.

Council staff observed that these basins have performed extremely well. They were not over-topped in the March 2014 storm event – as seen in photo below of the Awatea infiltration basins full of water. Note that the detention basin to right of photo has not started to fill with water.

6.3.2 Meadowlands

A similar approach is being negotiated with the developers of Meadowlands on Sparks Road. The proposal is to provide "Full Flood Attenuation" for the 50-year return period event and to retrofit mitigation for approximately 38 hectares of existing development in neighbouring Hillmorton. The development will also ensure that any filling of land within the natural floodplain of Hendersons Basin is kept hydraulically neutral by providing compensatory flood storage elsewhere on the site.

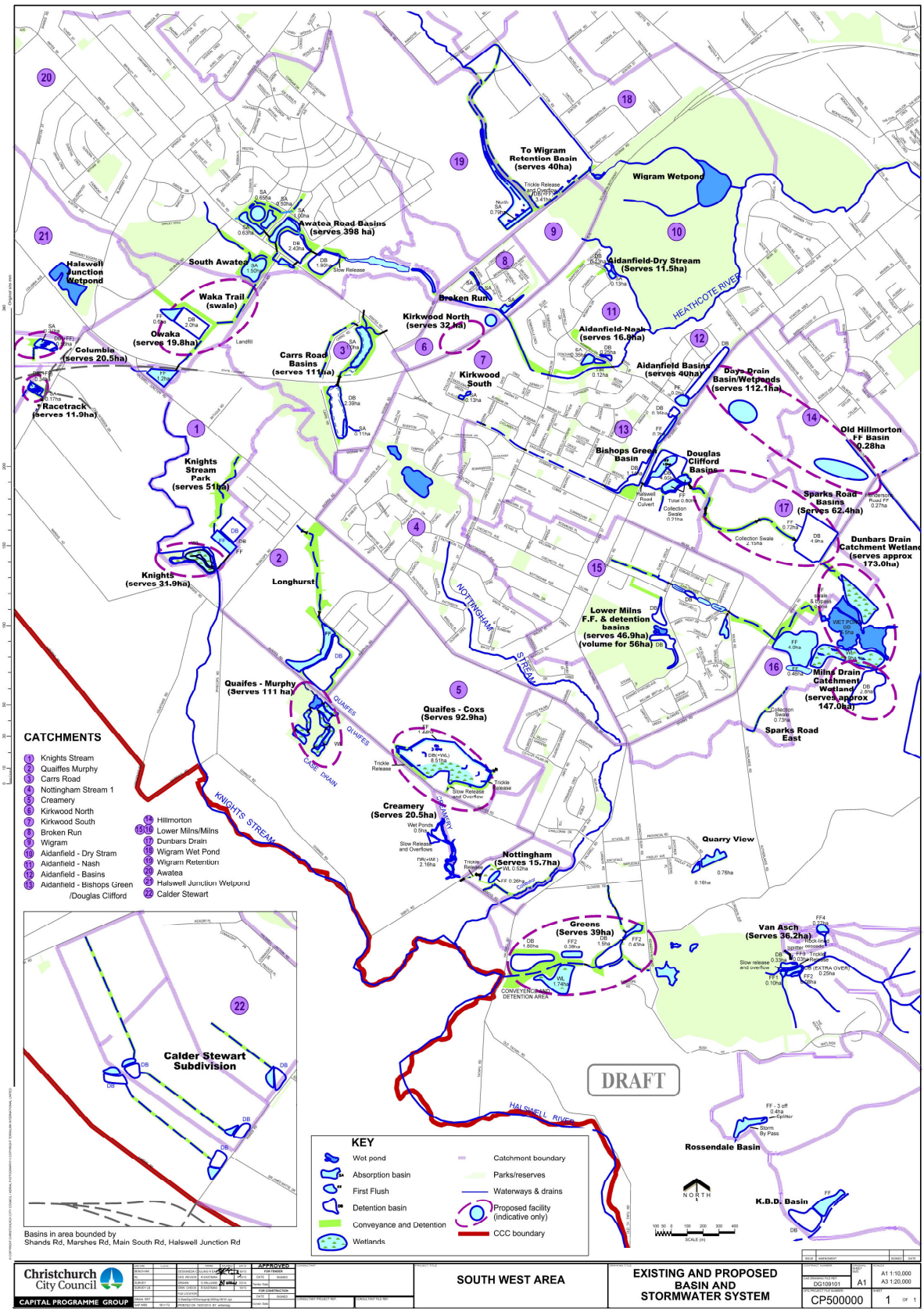


Figure 10 South West Area proposed basin and stormwater system

6.4 Styx Stormwater Management Plan

The Styx SMP was completed in 2012 and the stormwater discharge consent for the catchment was granted in 2013.

The blueprint specimen design for the Styx catchment sets out the proposed stormwater network including:

- Ponds and basins for detention and treatment
- Wetland areas.

As in the South West this network will be developed progressively over the next twenty to thirty years through a combination of Council initiated works and facilities built as part of private developments.

6.4.1 Prestons

The northern third of the Prestons development drains to the Styx and the southern two-thirds drains to the Avon catchment. The developer is required to provide for stormwater treatment and retention for a 50-year return period event.

Stormwater storage and wetlands are being developed by Council at Clare Park, to the east, to provide further secondary treatment or “polishing” and additional flood storage.

6.4.2 Highsted

Basins and wetlands are currently under design and construction, and the system will also service some 150 hectares of existing development to the south.

6.5 Ensuring compliance

The Council undertakes comprehensive evaluation of the design and monitoring of the performance of stormwater treatment facilities to ensure they are contributing to better outcomes for the catchment:

1. Subdivision consents specify conditions for stormwater infrastructure.
2. Detailed engineering plans and calculations for stormwater designs must be submitted and approved by Council engineering officers.
3. s224 issuance following provision of as-built plans complete with design report and actual basin volume calculations. Often includes robust testing of the performance of infiltration and detention basins
4. 12 months defect period to test the systems, ensure construction quality and obtain monitoring information.
5. Monitoring of water quality is undertaken across all city catchments on a yearly basis to track historical trends in contaminants and to help identify any problem sources of these, for example, industrial activities.
6. Sophisticated hydraulic river models are reviewed and updated to reflect new development and construction of new stormwater facilities and are calibrated after every major storm event.

6.6 Conclusion

It is concluded that current upstream developments are not worsening flooding and mitigation requirements are being fully implemented.

7 Community feedback on Council systems and processes

7.1 What did the community tell us?

During the public meetings held as part of the Taskforce, a number of common themes emerged in discussion with the residents who have had to deal with stormwater or flood related issues during the recent events which have been made worse by the earthquakes.

The three main areas of concern raised at a number of the community meetings related to:

- Customer Service Request (CSR) system
- The barriers to drainage and roading maintenance contract holders assisting outside of their contract scope
- No or limited regular maintenance observed

7.2 Customer Service Request System (CSR)

The Council has been using a CSR system called WorkSmart for well over a decade, which has been deferred for replacement on several occasions over the years due to the cost of change and other competing information technology priorities.

WorkSmart is part of the GEMS suite of products developed in 1995 which is now approaching obsolescence and is no longer supported. The main drawbacks of the system are that:

- It does not readily interface with the Contractors Workflow Management Systems
- Real time status updates are not available.

While our contractors have sophisticated mobile work management systems in place, Council systems are not sufficiently developed to make best use of the real-time electronic information contractors could provide.

Due to this shortcoming in the integration of systems, there has been a practice of using a 'Bulk Upload' process that allows contractors to close out batches of jobs with incomplete information, without necessarily validating whether or not they have been completed or fully closed out. While part of the issue is related to the age and functionality of the system, there are also user process issues that need to be re-engineered to produce improved performance and reliable outputs through to job completion and close out.

In the land drainage area, there are currently around 840 active jobs in the CSR system that need to be resolved and closed out. While this has reduced in recent months, the manual nature of the work imposes a significant drain on staff resources.

One clear message that came through from the community meetings was that the community did not have a great deal of faith in the CSR system. The common complaint was that while they received a CSR number from the call centre staff, they often never observed any action being taken as a consequence of their call and received no further feedback. While some at the meetings had more favourable experiences, the inconsistency in response to CSRs needs addressing.

Having encouraged the community to inform the council of defects or problems with services by phoning the call centre (24hrs) on 941 8999, it is apparent that there needs to be a commitment to ensure that each of those requests are well managed through to completion. This will require that each request, whether relating to stormwater or any of the other services provided, is:

- Guided through a logical business process
- Deployed to the appropriate service provider

- Closed with the appropriate information within the response commitment determined by the level of service agreed between the Council and the community

There are good examples of integrated Customer Relationship Management (CRM) systems that are in use in New Zealand and worldwide that seamlessly incorporate workflow management with customer service systems.

7.2.1 Recommended action

It is recommended that the project to review the (CRM) process and replace WorkSmart be given a high priority in order to deliver early benefits across the Council.

7.3 Contractor demarcation

Another observation many made at the public meetings was the apparent demarcation of different contractors they spoke to during storm events. For example, roading contractors who are concerned primarily with road related stormwater infrastructure such as roadside catchpits, slips onto roads and road pavement flooding, were unable to assist with a problem on a land drainage asset that was outside their contract scope. Conversely, but to a lesser extent, land drainage contractors are focussed on servicing the stormwater pipes and watercourses but not the roading stormwater infrastructure. In some cases it was claimed that there was a reluctance by contractor staff to assist as they risk not being paid for work done beyond their contract scope.

These were anecdotal reports from individuals and Council Contract Managers encourage “can-do” behaviours from contractors particularly during extreme events. This does happen and has been observed during these events. However, the perception by the community can often be influenced by the poorest example they witness.

There is a further demarcation where stormwater management on State Highways falls within the jurisdiction of NZTA, and hence the responsibility of yet another entity and contractor. While staff and contractors may be familiar with these organisational arrangements, the general public are not.

7.3.1 Recommended action

The boundaries between different maintenance contracts of land drainage components should be reviewed. At present there are three different maintenance contracts governed by different sections in Council as follows:

- Gutters, sumps and the lead to the main pipe – Roading
- Pipes and surface water channels – Land Drainage
- Basins and wetlands - Parks

It is recommended that a review take place to ensure that these boundaries do not cause inefficiencies or issues, particularly during extreme events.

7.4 Limited or no regular maintenance observed

There were a number of occasions during the public engagements where the frequency of routine maintenance of stormwater infrastructure was questioned, and claims made that parts of the network had seen no or very little regular maintenance post-earthquakes.

While the land drainage team have established “rounds” for the contractor to undertake on a routine frequency, there is limited feedback to the Council of specific times, dates, location, condition and defect data that would validate all of the maintenance work carried out by the contractor. The Council’s asset management information system has not yet been developed sufficiently to accommodate this data for land drainage work, although maintenance contractors currently do this internally. In the absence of a comprehensive maintenance and asset history, there is no basis to dispute the claims of the residents who often take a keen interest in the work going on in their neighbourhoods.

7.4.1 Recommended action

The routine maintenance "rounds" should be revised based on the findings from the Taskforce work, and a planned maintenance scheduling system be investigated to assess the benefits of automating the issue of routine work instructions to contractors. This would potentially provide a means to monitor and optimise routine maintenance activities. It would also provide asset and customer information back from the field that can be recorded in Council's Asset Management Information system including:

- Job completion dates and times
- Details of asset condition
- Proof of presence using GPS
- Job costs

Note that this may require an increase in the Land Drainage Operations budget to accommodate this change.

Figure 11 Maintenance in Truscott Drain July 2014

7.5 Case Study – Scottish Water

An example of where the benefits of integrating Customer Relationship Management systems with Asset Management Information and Mobile Field applications was demonstrated in Scottish Water, when their solution was implemented in 2009.

Smart Technology Solutions

Efficiently managing over 30,000 reactive and routine work order tasks undertaken every month across Scotland requires some careful planning and scheduling using some very powerful work management and dispatching systems.

Mobile computing trials first began in Edinburgh and were incorporated with their Customer Relationship Management (CRM) system ("Promise" from Oracle). This application was purchased "off the shelf" and business processes were adjusted to fit application rather than altering the application to fit their process. Oracle met the challenge to deliver a working product within 12 weeks.

An advanced scheduling tool named "Click" was integrated with the CRM which provides advanced telematics in vehicle. The daily work diaries of over 600 operatives across the country are pre-populated by the system based on the current planned workflow and reactive maintenance service requests are incorporated into the scheduler and dispatched, according to their priority.

Two telemetry open enterprise (OE) SCADA systems are utilised; ICC - Intelligent Control Centre and WMS – Water Management System. Seven former regions are now managed as four and are moving to intelligent alarms that can reduce call outs and overtime. This means that they can move to a 1 in 6 or 8 week standby instead of 1 in 3 or 4.

The "Documentum" document management system (From EMC) is used for hosting and content management of various documents and procedures across the enterprise.

Single mobile gateway – Oracle Mobile & IMS, went live in Feb 2009 across 8 regions. Used by 150 E&M staff, 600 field staff run by 40 back room support staff. Service Level Agreement compliance went from 40% to 75% within that time (12 months) and more jobs are now closed off, sooner.

Oracle Mobile & IMS – to 600 field staff. SLA compliance improved from 40% to 75% in 1 year.

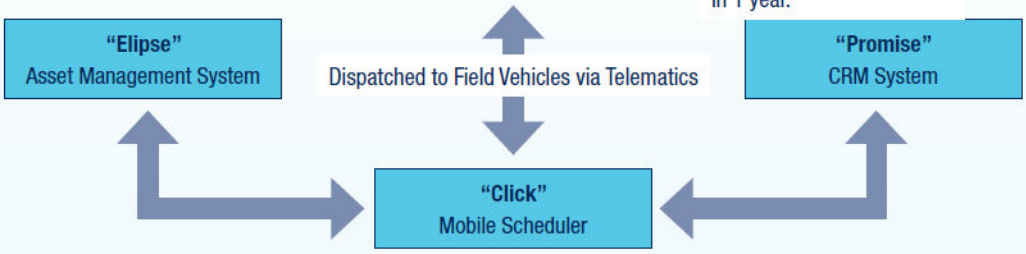


Figure 12 Scottish Water customer relationship system[4]

[4] Mackie,J, New Zealand Water Journal; *The Scottish Water Experience*, Water NZ, (Nov 2010).

Section B: Short-Term flood defence measures

8 Selection criteria

Short-term flood mitigation measures must:

- Be quick to construct (i.e. built within 12 months) with a preference for those that can be carried out sooner
- Significantly reduce regular flooding effects to houses in **the first level of vulnerability** where practicable
- Prevent flooding under the houses in **the second level of vulnerability** where practicable
- Be cost-effective and affordable for Council and other parties who may need to bear the cost
- Be consistent with long term plans, including the Integrated Catchment Management Plan for each area

The lowest cost options have been proposed. Where costs are similar for two options then preference will be given to mitigation measures that improve occupancy and help avoid concerns about unoccupied buildings.

The short-term flood defence measures fall into three main groups:

- Single house defence
- Maintenance
- Local area schemes (benefiting more than one house)

These are described in the following sections. In each area there are likely to be a combination of different measures as needed to reduce flooding effects in the priority areas.

9 Design standard and levels of service

The vulnerability levels used by the Taskforce are not intended to replace Council's current level of service. Rather, the vulnerability levels are a methodology developed to assess house and household vulnerability following a specific series of events. Whilst compatible with Council's existing levels of service, a planning and policy review should be undertaken if they were to be used outside of this context.

9.1 Infrastructure design standards

Design standards for new subdivisions ('greenfield development') within the City are set within Council's Infrastructure Design Standard, and illustrated below (Figure 13).

- Roads to remain clear of surface flooding up to the 20% Annual Exceedence Probability (AEP) event (equivalent to a 5 year average recurrence interval)
- Flooding to be contained within the road reserve up to the 20% Annual Exceedence Probability (AEP) event (equivalent to a 10 year average recurrence interval)
- No floor level flooding in a 2% AEP event (equivalent to a 50 year average recurrence interval)

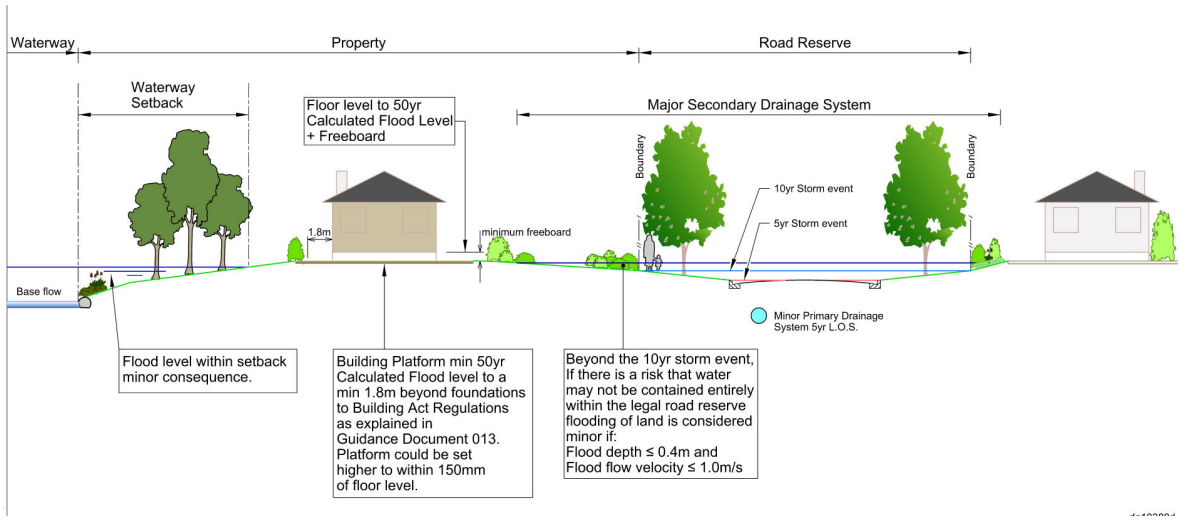


Figure 13 Minimum floor levels (Infrastructure Design Standard)

The proposed temporary flood defence measures will not be able to achieve a similar design standard as they are proposed within existing development areas and are heavily constrained. Where possible they should be designed to:

- **House defence:** If house defence is proposed it should be constructed to a 2% AEP flood level with freeboard as it is easily achievable to do so.
- **Local area schemes:** A design standard equivalent to a 10% AEP (i.e. a 10 year return period) should be used. This is approximately equal in size to the second largest rainfall event observed across the city since the earthquakes (and would defend against all of these events but the March event).

9.2 Level of service for flood protection and control works

The current level of service for flood protection and control works is to ensure that dwellings are safe from flooding during normal rain events. The target is that no more than 0.25% dwellings in Christchurch are flooded per year (based on a 50 year rain event).

The Taskforce has not assessed the number of dwellings flooded in 2014 in events less than 50 years. The Taskforce numbers report total numbers of dwellings and does not sum up multiple instances of flooding.

Figure 14 Flooding along the Lower Avon

10 House defence measures

House defence measures are property specific responses which aim to reduce damage to a house from flooding (Appendices B and C). The measures can be either temporary or permanent and may involve physical changes to the house (e.g. house raising or house tanking) or installing flood barriers on the property.

These measures include:

- House raising

- Sand bagging

- Property re-grading

- House tanking

- Relocation

Many of these measures can be installed by home and business owners to protect their property. Tauranga City Council and other international agencies have promoted house defence as a viable flood defence measure. A pilot study investigation of these measures on a house in the Residential Red Zone is currently in development to validate the approach in Christchurch conditions.

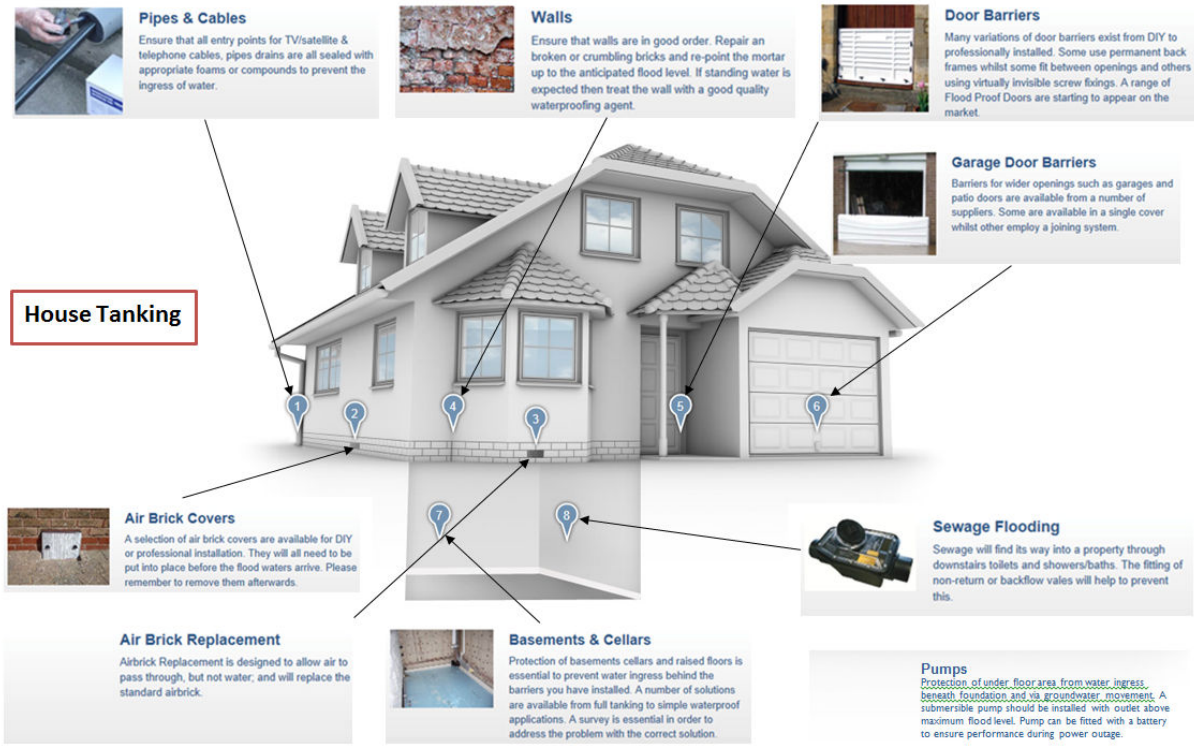


Figure 15 House tanking options (Source: thefpa.org.uk)

11 Maintenance measures

Maintenance measures are operational responses before, during or after flooding events to ensure that the network performs as designed. The Council contracts for Maintenance of Waterways and Land Drainage and the Road Maintenance are key instruments in maintaining the performance of the network.

There are four Road Maintenance contracts and one Waterways and Land Drainage maintenance contract covering the greater Christchurch area, including Banks Peninsula.

The *road* maintenance contract includes:

- street cleaning
- cleaning pipes between sumps and the main
- cleaning sumps

The *waterways and land drainage* contract comprises the following primary categories:

- General Waterways Maintenance
- River Maintenance
- Stormwater Reticulation Maintenance
- Tributary & Utility Waterway Maintenance
- Waterway Maintenance Items
- Stormwater Reticulation and Backflow Control Valve Maintenance
- Supplementary Maintenance Information

Maintenance measures include clearing, cleaning, repair or replacement of:

- Grates or screens

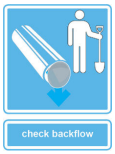
- Sumps

- Streets

- Pipes

- Obstructions

- Check backflow



Maintenance measures already take place and any change to the current operational regime needs to be considered within the context of the larger catchment maintenance to achieve cost efficiency.

Refer to Appendix A for further details on each of the maintenance solutions.

12 Local area schemes

Local area schemes are measures which are implemented over an area to help reduce the effects flooding at multiple properties (but do not prevent flooding). The measures can be temporary or permanent and may involve physical changes to Council assets and/or private property. They may also involve enforcement of District and Regional Plan policies. The local area schemes will typically involve multiple measures.

These measures protect multiple houses from flooding and are detailed on the following pages. These include:

- Local bunding

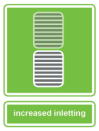
- Debris screens

- Diversions

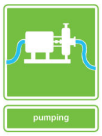
- Enlarged drains

- Flap gates

- Increased inletting



- Pumping



- Raise existing stopbanks

- Sand bags - street

- Secondary flood paths

- Setback enforcement

- Dredging

- Temporary bridges

- Temporary surface storage

- Traffic management

Further detail on each option is provided in Appendix A.

13 Concept sketches

The following concept sketches illustrate potential short-term flood defence measures. These depict multiple measures implemented at each location. Typically only one or two measures would be implemented at each house or location.

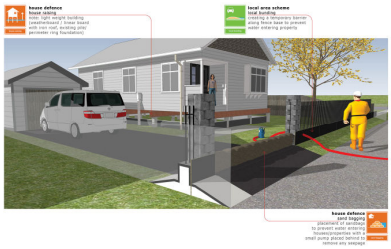


Figure 16 illustrates a single house that has been raised. Re-grading, sand bagging and a local area bund are also shown.

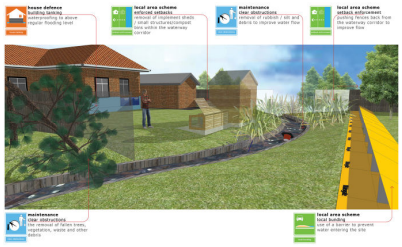


Figure 17 also shows a single house, but with a waterway through the rear of the property. The house has had a tanking solution applied and setbacks have been enforced. Also shown is increased maintenance in the waterway and a bund to provide flooding defence to other properties.

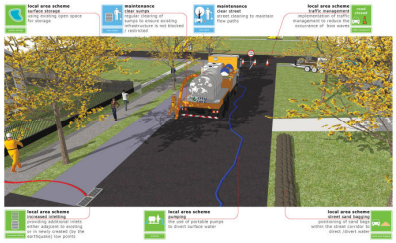


Figure 18 shows a street with a range of measures. These include both maintenance, and also installation of sand bagging, pumping and surface storage.

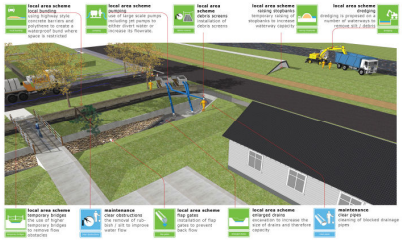
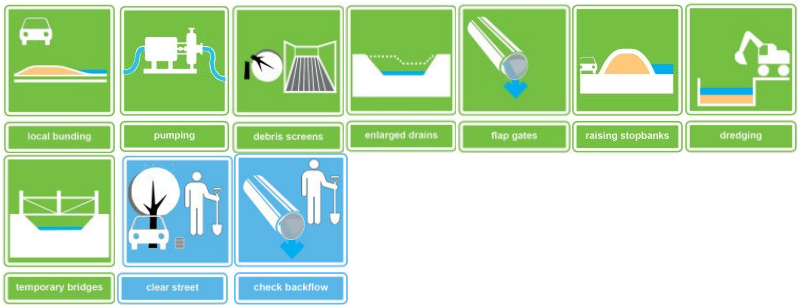


Figure 19 shows a catchment-scale local area scheme. This shows a much wider range of measures being implemented which affect more than a single house.



Each of these measures is described in detail in the sections following the concept sketches.

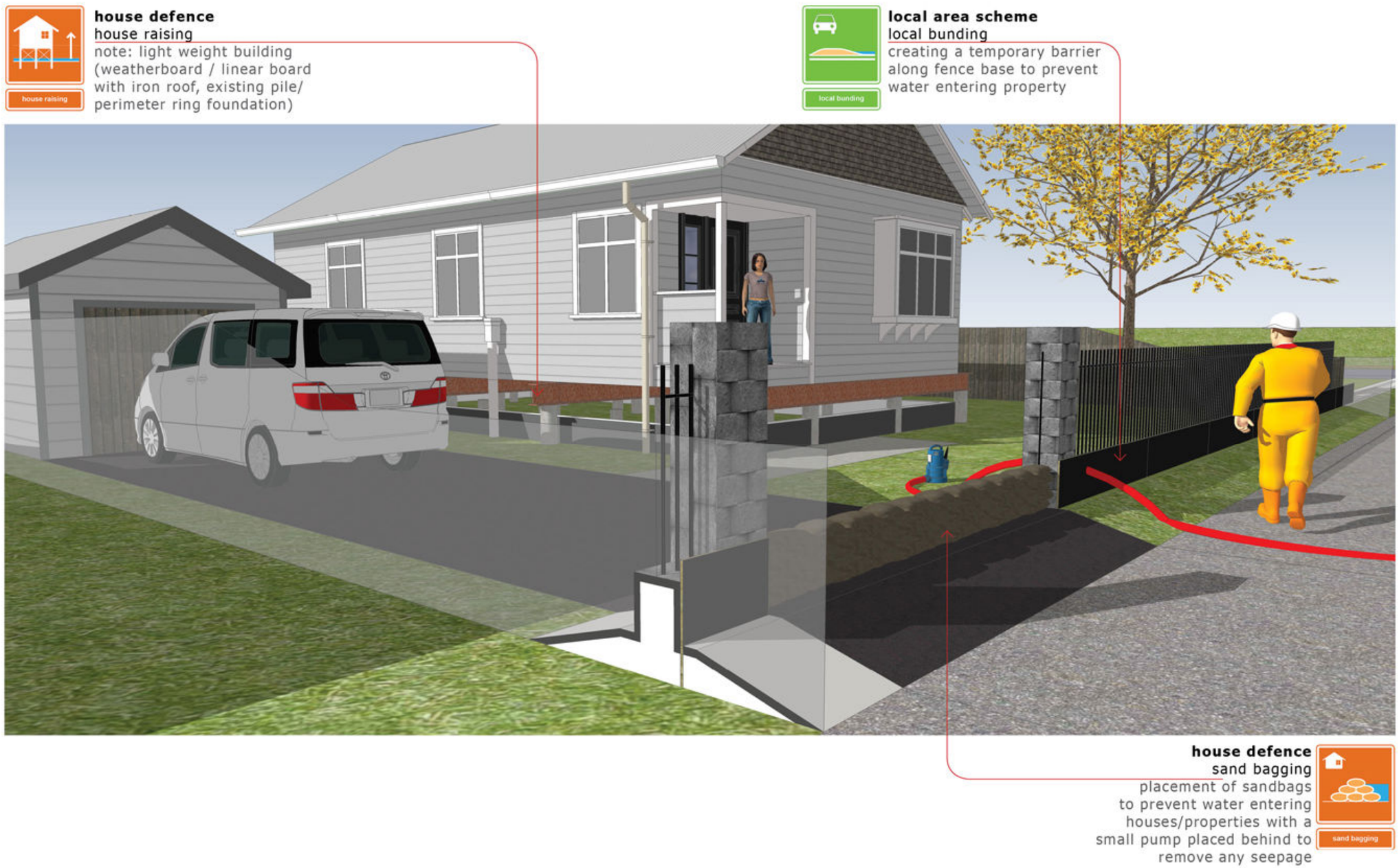
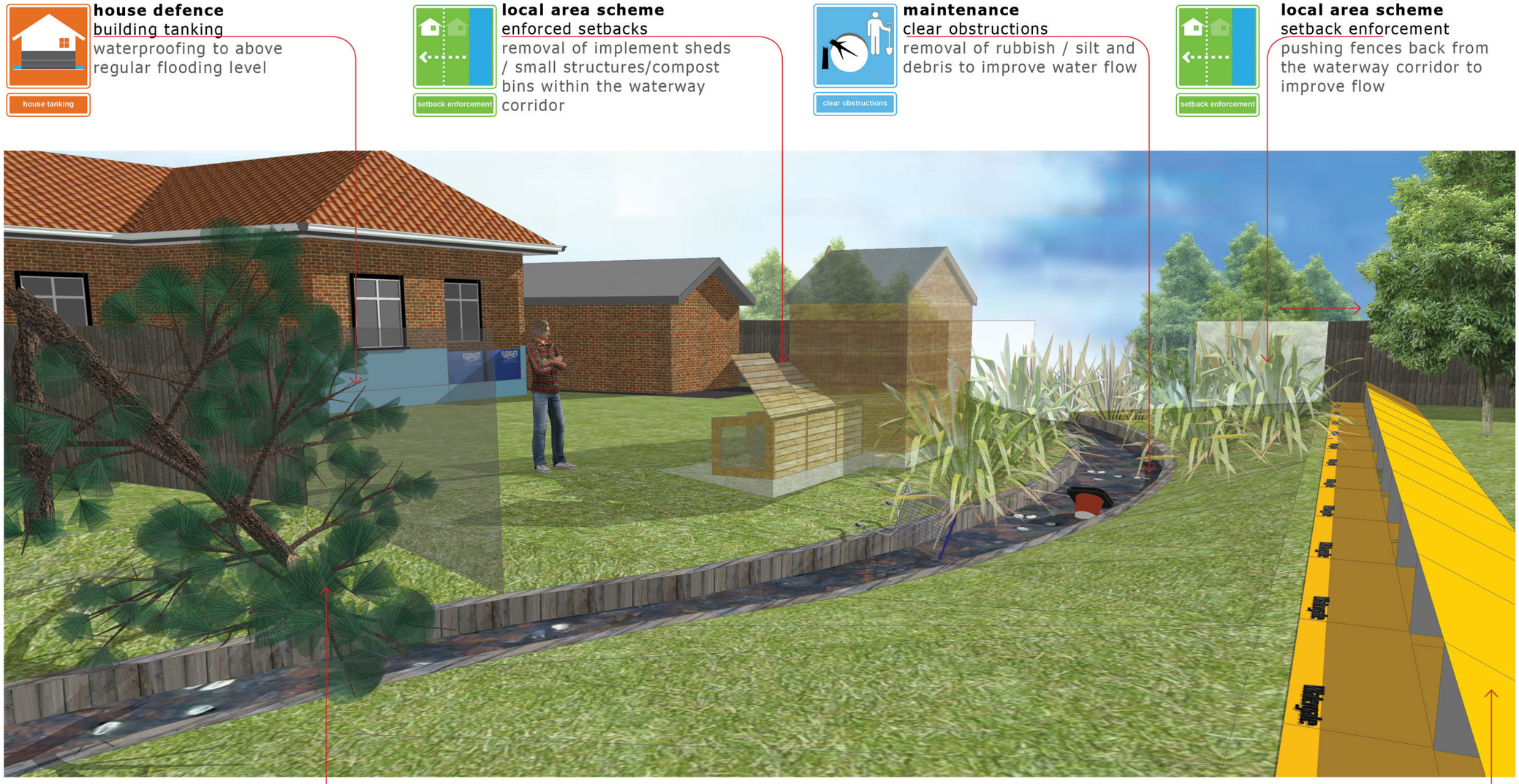


Figure 16 Illustration of house defence measures – example one



house defence
building tanking
waterproofing to above regular flooding level

local area scheme
enforced setbacks
removal of implement sheds / small structures/compost bins within the waterway corridor

maintenance
clear obstructions
removal of rubbish / silt and debris to improve water flow

local area scheme
setback enforcement
pushing fences back from the waterway corridor to improve flow

maintenance
clear obstructions
the removal of fallen trees, vegetation, waste and other debris

local area scheme
local bunding
use of a barrier to prevent water entering the site

Figure 17 Illustration of house defence measures – example two

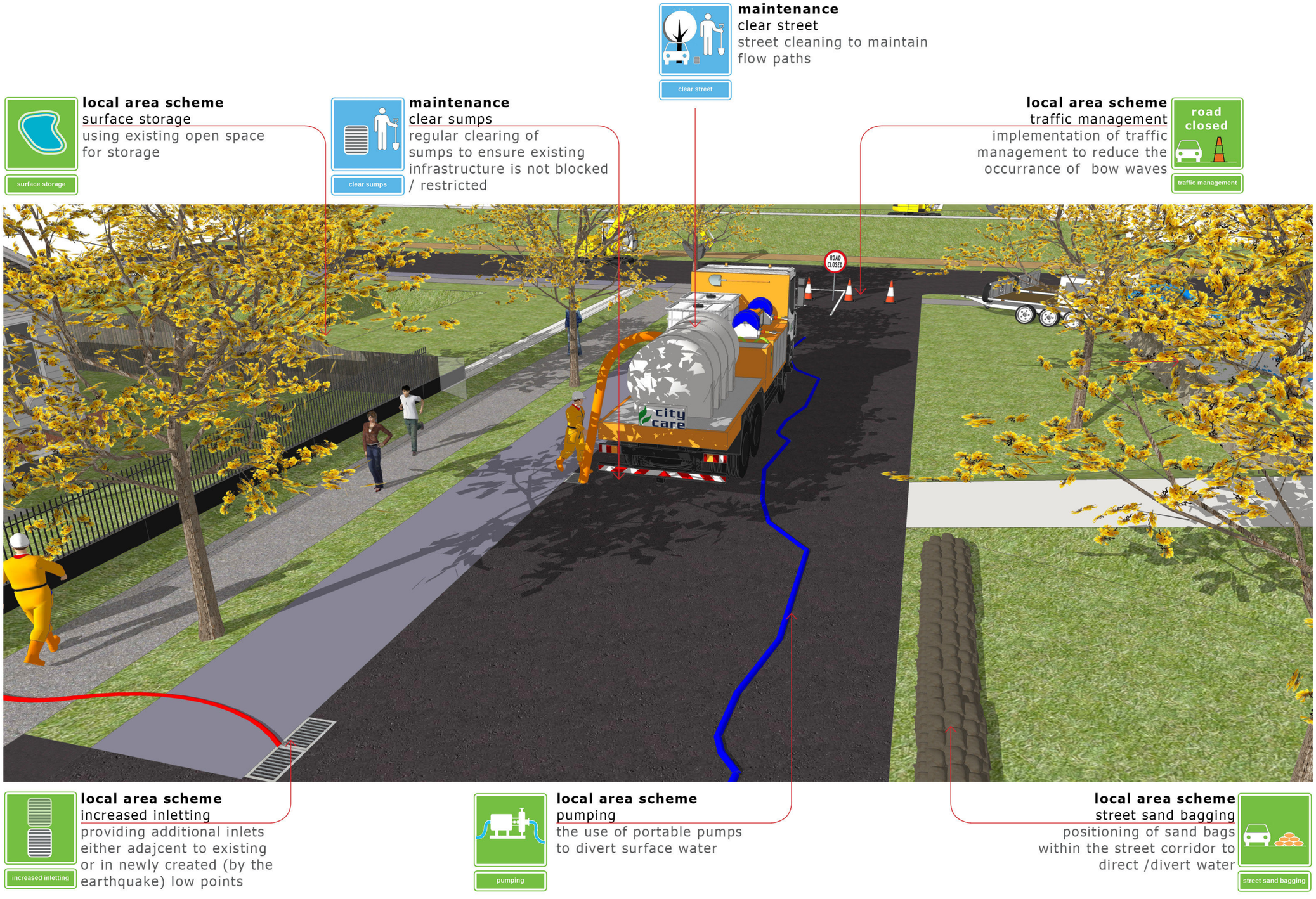


Figure 18 Illustration of local area scheme – street example

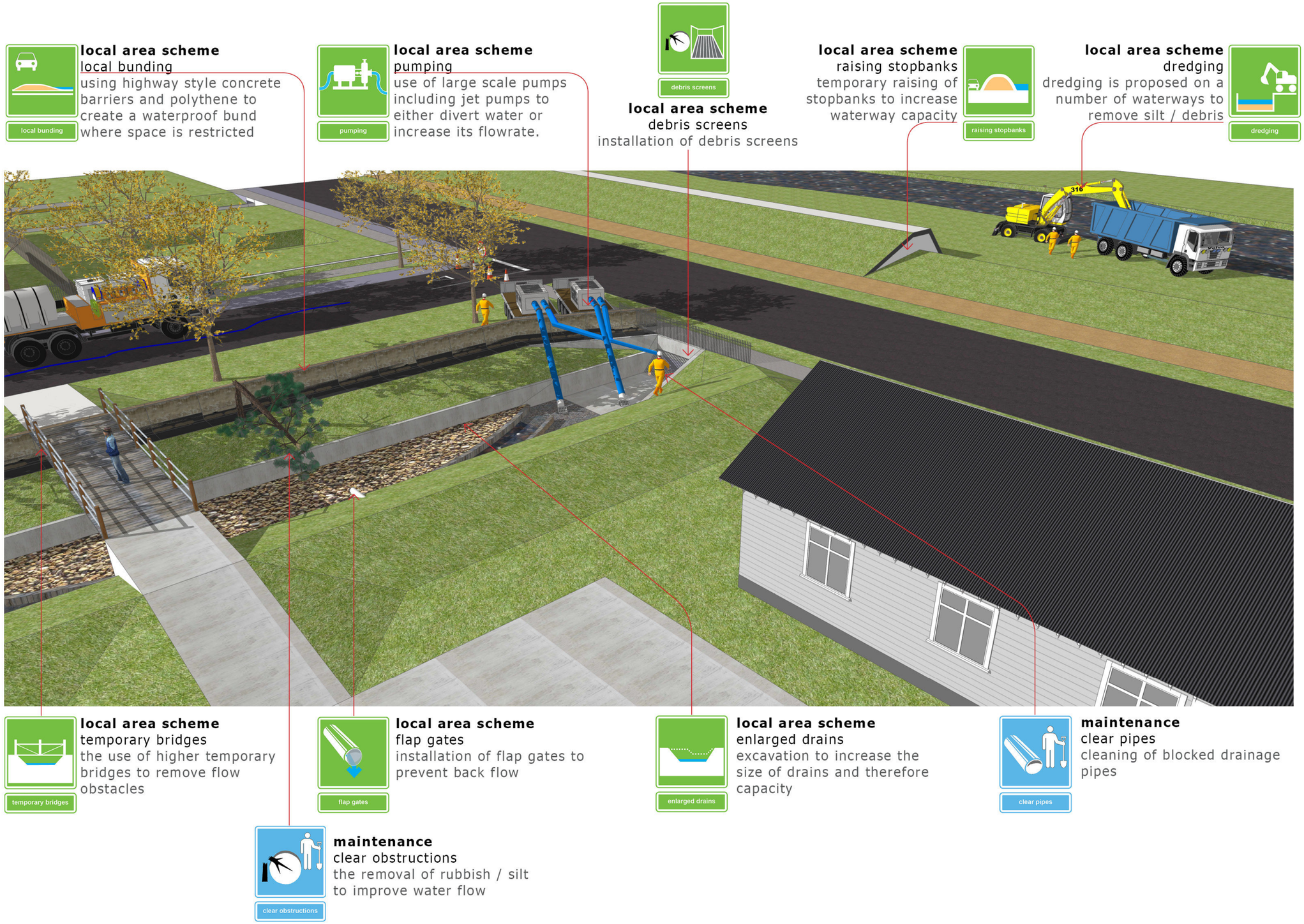


Figure 19 Illustration of local area scheme – catchment example

14 Dredging

Dredging was identified as a potential short to long term solution to reduce flooding in the Avon and Lower Heathcote Rivers. The Avon River was not considered further when no Level 1 properties were identified in this area.

The Lower Heathcote River was studied in more detail as there are a number of Level 1 properties in that area. Dredging in this area has often been proposed as a flood mitigation option, due to ongoing sedimentation and an excess of material deposited in the river post the 2011 earthquakes. Some initial hydraulic modelling indicated that there may be some benefit to flood depths if this material was removed.

Siltation of the river occurs mainly due to the deposition of material transported from the Port Hills and will continue at a steady rate going forward. The river currently holds in excess of 130,000 m3 of material in comparison to 1990 bed levels. Historical dredging occurred between 1927 and 1989 removing considerable amounts of silt from the river. Flood events occurred during this time period and were equivalent to and at times worse than the March 2014 event. This indicates that previous dredging did not remove risk to properties in large flood events.

Modelling of the March 2014 event has now been completed with the recalibration of the model to take into account more accurate data. This has been compared with the surveyed flood levels undertaken following the March event and provides confidence in the model. A post dredging scenario has been run through the model and the results show a benefit of reduction in flood level by up to -0.3 m in some areas. Taking into account a model tolerance of + / - 0.3 m this could provide dredged flood level difference of between -0.60 m and 0.0 m.

Dredging modelling shows that in the best case scenario flooding over the floor level would be prevented for the 13 Level 1 properties in the Lower Heathcote priority area. If a worst case tolerance of +0.30m is applied then only 7 Level 1 properties still benefit.

In addition to benefits for Level 1 properties, some Level 2 properties would benefit from reduction in under floor flooding.

The estimated costs of dredging once is $16 million. The frequency of dredging has not yet been determined.

A dredging feasibility report is currently in review stage.

Figure 20 Dredging on a UK river

15 Private drainage issues

Private drainage issues arise when a house or property cannot drain to an outfall. Outfalls can be natural or engineered. Natural outfalls include streams, watercourses, the estuary or the coast. Engineered outfalls include those from Council land drainage or roading networks. Typically houses within Christchurch drain to an engineered outfall on a street. Problems can arise if:

- There is no connection to an outfall
- There is insufficient fall between the lowest point on a property (possibly where the house is built) and the outfall
- The connection (i.e. the private stormwater pipe) is damaged or too small

The ability for private property to drain to an outfall has often been affected by land damage. If a property has dropped relative to the outfall (e.g. it is now lower than the road) then the stormwater cannot all discharge to the Council network.

Private property drainage issues were not a focus of Taskforce investigations but did record and report these houses as vulnerable where they met the criteria for frequency of flooding and were identified in field inspections triggered by residents reporting flooding. A total of 24 of the reported flooded properties were assessed as having flooding resulting from private property drainage issues (Table 6).

Table 6 Private property drainage issues

Vulnerability Category	# properties with private issues
Level 1	3
Level 2	7
Level 3	9
Not Vulnerable	5
Total	**24**

It is likely that the figures above are a significant underestimate of the scale of the problem as these issues are under-reported by residents. Council has attempted to assess the potential scale of the issue through separate investigations (utilising computer based ground modelling techniques). That investigation concluded that about 25% of properties may have some part of the property which may have a problem draining to the road (at least 5 m^2). On an individual property there may be earthquake effects which have made the problem worse or better, with some properties where the problem may not have existed prior to the earthquakes. Overall, the vast majority of those with post-earthquake drainage issues had them prior to the earthquakes and that the earthquakes have not changed the scale of the problem. This analysis does not attempt to assess the impacts of the problem on the house.

Council is presently not mandated to deal with private property drainage. Council is required to provide an outfall for every rated property (i.e. a street connection or access to a waterway), and connection to this outfall is the property owner's responsibility. The Taskforce has not developed local area schemes to address these issues or included house defence measures for these properties within the cost estimates.

There are many ways in which residents can reduce the impacts of this type of flooding, and the first point of contact should be with a drainlayer.

16 Identification of consenting issues

16.1 Regulatory approvals

A full assessment of statutory considerations and planning requirements has not been undertaken. However, the following section describes the generic considerations for the temporary flood defence measures.

Some statutory approvals will be required. The methods of gaining approval to undertake the works include:

- Use of relevant existing global consents held by Council, if applicable
- Seeking project specific RMA consents
- Seeking a Notice of Requirement (NOR) to designate the public works
- Use of the Canterbury Earthquake (Resource Management Act) Order 2011 (SR 2011/34)

Various consents are held by Council in order to undertake post-earthquake and routine maintenance and upgrade works within watercourses.

Some of the defence measures proposed affecting the beds and margins of waterways will be covered by the global waterways consent so long as certain conditions and legal requirements are met. Conditions include notification of Council's key partners, e.g. ECan, Historic Places Trust and Mahaanui Kurataiao (MKT).

Some works are excluded (or not specifically included) in the global consent and all measures will need to be assessed for consent requirements. Consents may also be required for works if contaminated material is to be disturbed or if excavation exceeds the allowance under the Global Consent.

Note that any consents gained under the RMA will not provide the rights of access necessary to give effect to the consents.

If property access is required then options for this could include a Notice of Requirement or Use of the Canterbury Earthquake Order. Due to the greater power of these approvals, they would provide greater certainty for the measures, but may risk causing further distress to those adversely affected.

16.2 Building Consents for house repairs in areas of increased flooding

The Taskforce is aware of a problem in relation to buildings that are located in areas subject to increase flooding vulnerability following the earthquakes. The issue is that insurers are only raising house floor levels where the house foundations are being fully replaced or the insurer is building a new house for their client. Where earthquake damage to a foundation is being repaired there is no requirement to raise the floor level of the house even if it is subject to increased flooding vulnerability. This is leading to houses being repaired and completed in areas that now flood. The Building Act 2004 process (section 17 and section 112 additions and alterations to a building) prescribes the extent to which Council can require upgrades to existing buildings.

The Taskforce understands that Council is currently working on this issue and is seeking the assistance of the Ministry of Business, Innovation and Employment to investigate ways in which the Building Act 2004 could be amended to require the floor level of a building to be raised where that property is subject to increased flooding vulnerability.

16.3 Property owner agreements

Land owner's consent will be needed for any work done on private land (such as house defence measures). This consent will need to be a formal document that outlines any liabilities and the effects on the property. This is particularly important for the house tanking work which is a relatively new technology.

16.4 Recommendations

It is recommended that strategies are developed to ensure all relevant consents and statutory requirements are addressed. The following would help to inform the development of such strategies:

- Consultation with ECan to explore the applicability of existing consents to each measure
- Undertake consultation with directly affected property owners to gauge their views and position with regards to granting Council access for the proposed works
- Undertake consultation with key stakeholder groups to seek their views

Council will then be in a position to better understand the risks associated with each consenting and property access approach, which will directly influence the ability to deliver the defence measures.

17 Information, awareness and response measures

17.1 Public data access

17.1.1 Background

Council currently have data for a number of rain gauges and stream gauges (level and flow). Publicly available information includes:

- Data from several level and flow gauges on the ECan website
- Several rain gauges through NIWA's CLiFlo database (although there is no live feed with data only available following periodic updates)

Information available to selected Council officers includes:

- Rain and stream gauges via NIWA's NEON website using a Council login
- An additional rain gauge located near the Brougham-Colombo intersection via AWT's website (requires a Council login)

Rainfall totals and intensity for the previous hour can be obtained from the MetService website for Christchurch Airport and for the Port Hills near Sugar Loaf. Council and CERA are looking to install a fire weather station on the Port Hills (at a site east of Victoria Park) which will provide real time rainfall data. This will provide useful information as the Port Hills contribute significantly to the flow in the Heathcote River during heavy rainfall events.

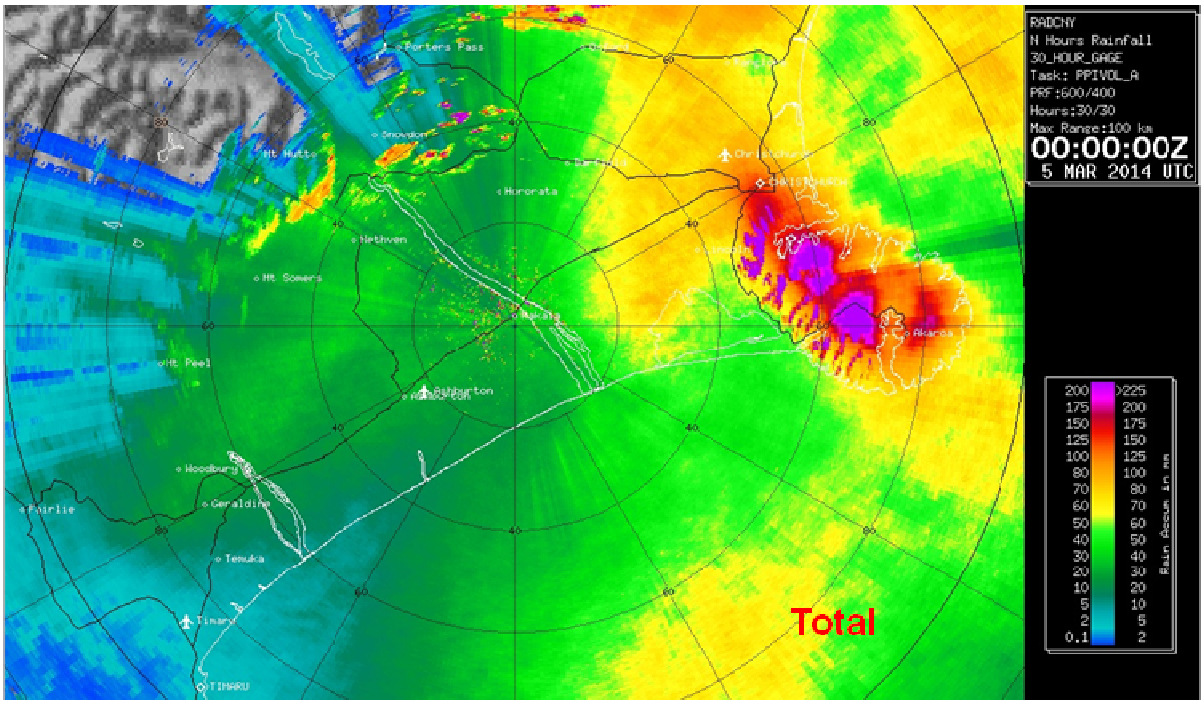


Figure 21 Gauge corrected radar showing March 2014 storm depth

17.1.2 Opportunities

Access to live data feeds allows the public to be informed and up-to-date, and may relieve anxiety over not knowing what is happening when away from home. It will also allow residents and the media to monitor rainfalls, flows and river levels to help them plan and make decisions around their properties. The greatest benefit would be to store all the data at one location.

Collation and presentation of all this information in one location obviously presents some technical issues, particularly from a web development point of view. However, Marlborough District Council

currently has such a system operating (http://hydro.marlborough.govt.nz/floodwatch/), a screenshot of which is shown in Figure 22 below. This website shows the river flows, river levels (with warnings for various levels of flood) and rainfall for the district and data is refreshed every five minutes.

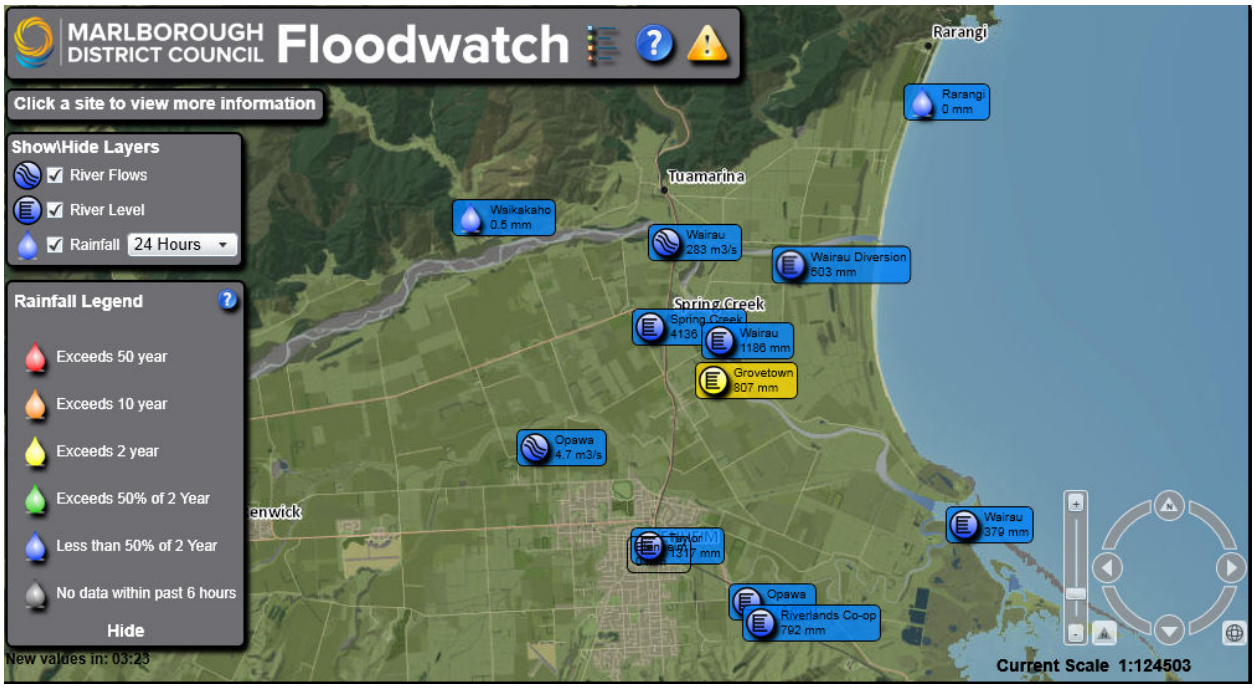


Figure 22 Marlborough District Council Floodwatch website

17.1.3 Options

In the short term, it may be simplest to incorporate the various data sources into ECan's existing webpages for rainfall and flow data. ECan have expressed willingness to host the data and assist in getting the data onto their website. This allows for the data to be made public quickly. It is also an existing resource that people use to check rivers such as the Avon and Heathcote. ECan's webpages for viewing life data feeds work well, are easy to use and are already known to the public.

In the longer term, Council may prefer to develop its own webpage to host this data.

17.2 Health awareness

Discussions were held with Canterbury District Heath Board (CDHB) to develop a Frequently Asked Questions and responses information leaflet (available online). This document provides guidance and information on the following issues:

- Health risks associated with contaminated flood water
- General hygiene advice related to human contact with contaminated flood waters
- Advice on how to clean up your section after a flood event
- Lists of agencies that can provide help or assistance in relation to section or property clean up e.g. civil defence, Salvation Army etc.
- The process of how to log a call with Council to receive assistance with section clean up
- Advice on natural processes which kill off contaminants in flood waters
- Advice on methods to increase ventilation and reduce mould and dampness following flood events
- Advice on how to clean up your property internally after flood damage

- Community assistance available in relation to anxiety, stress and depression issues

A single point of contact in Council could be appointed to deal with and provide assistance and advice to residents in flood prone areas.

17.3 Rainfall warnings

Council currently receives rainfall forecasts and warnings from MetService (MetConnect) and other providers (Blueskies and Aurecon). For the past year CERA has received forecasts and warnings (for seven days in advance) with a particular focus on the Port Hills area. Forecasts and warnings could be updated to include rainfall thresholds associated with risk and response.

Weather is complicated and dynamic, and prediction of significant weather events requires close monitoring. Council currently monitors the predicted weather for seven days in advance. If there is a risk of a significant weather event (such as more than 50 mm expected within 48 hours) commencing within the next two days, then a higher level of weather monitoring and rainfall prediction is put in place until the risk is over. During this time regular updates could be provided to the public two or three times a day. This could be enhanced with access to a qualified meteorologist to provide briefings and answer questions.

17.4 Temporary response procedures

17.4.1 Background

There are two types of existing responses to a rainfall event: Council's wet weather operation response and a Civil Defence emergency response to flooding. The response depends on the severity of the rainfall.

Council operations teams and contractors respond to heavy rainfall, with the following responsibilities:

- The wastewater operations team has an overflow response plan that handles wastewater overflows, waterway contamination and wastewater flooding on private properties.
- The land drainage team has a list of prioritised locations for visiting and clearing / maintenance.
- The roading team deploys its maintenance contractors to prepare for forecast storm events and undertake emergency work and road closures where required.
- City Care has a waterways flood response procedure and a general emergency and recovery plan.
- Fulton Hogan is responsible for implementation of an emergency response plan for the Avon River stopbanks

Figure 23 City Care emergency flood response teams on Hills Road

17.4.2 Issues

Community feedback on the Council's wet weather response in the Flockton Basin has generally been positive, indicating that the Council's level of response is appropriate. There may still be scope to further reduce distress for the worst affected residents, particularly in areas where large insurance excesses are being imposed.

Given the flood prone nature of some areas and the time needed to implement solutions, it would be prudent to review the response procedures and Council policy for response and clean-up. The review should focus on steps to reduce the hardship for the most flood-prone communities until longer term solutions are in place and incorporate any findings from the Taskforce.

Current issues are:

- Temporary response plans have been developed for most areas of the city. However to ensure these are correctly carried out it is critical that the Council's response procedures include these individual plans, and reflected in the land drainage and roading contracts.
- Council response is managed by different teams and individual team responses may not be fully co-ordinated or cover all affected areas.
- Wastewater overflow response procedures focus on river corridors or individual Customer Service Requests (CSR) and do not extend to areas such as the Flockton Basin unless CSRs are received.
- Clean-up of wastewater contamination in private houses is done after a CSR or in the case of serious clean-ups is left to insurance companies to handle.
- The most vulnerable areas are now facing large insurance excesses forcing residents to pay for future damage and property clean-up / disinfection adding further distress and burden.
- Council staff may not have the resources to deal with wide-spread flooding and at the same time to carry out the area-specific response plans being developed.
- Residents have expressed concern about health issues after flooding, particularly about mould and dampness under their houses. High insurance excesses may be preventing some residents from drying out and cleaning their properties properly after a flood.

17.4.3 Options

We have identified the following options to improve the situation in flood prone areas in the short term until longer term solutions are implemented:

- Review wet weather response plans to ensure they are fit for purpose and incorporate any findings from the Taskforce
- Design new temporary response procedures to respond to wastewater contamination of flood waters in flood-prone areas away from the main river corridors. These could include:
    - posting contamination signs
    - notifying affected parties of health risks
    - advising about post-flooding clean-up
- In areas facing large insurance excesses and until longer term solutions are in place, Council may consider providing guidance and advice about access to funding for post-flooding clean-up

17.5 Education and community resilience

Educating communities on the function of the local drainage network and the roles of individuals, the community and Council would aid in identification of maintenance issues within the network and

minimising the risk of setback encroachment. Promoting the community as custodians of the drainage system could reduce flood effects by engaging members of the public in helping to keep drains and sumps clean and clear of rubbish and debris. This could involve simple tasks such as cleaning gutters and the local road sumps or more complex tasks during structured field days (similar to planting days).

This could run in parallel with an enforcement programme for illegal dumping and setback encroachment.

The result would be a more resilient community more able to respond when flooding occurs.

17.6 Information, awareness and response recommendations

It is recommended that:

- Rainfall and river level and flow data is made available to the public, preferably via a website
- A single point of contact in Council be appointed to deal with and provide assistance and advice to residents in flood prone areas
- The CDHB FAQ on the health effects of flooding be made available on the Council website
- Review and update wet weather response plans based on Taskforce findings
- Develop a package of information sharing methods to update and inform residents on flooding matters

Section C: Area Reports

This section firstly outlines the methodology developed to assess each area and identify appropriate short-term flood defence options. It then provides an area-by-area analysis of the cause/s and scope of flooding problems in each of the priority areas based on field visits that took place May and June 2014. This includes assessments of the contribution of earthquake-related damage to land and drainage systems, as well as identifying appropriate short-term flood defence options.

The information included in this section is summarised from the detailed area reports in Appendix C. The Taskforce has prepared a breakdown of each local area and maintenance scheme, including a detailed cost schedule and implementation programme should these schemes go ahead.

18 Dudley Creek

The Dudley Creek priority area is shown on Figure 26. It includes what is known as the Flockton Basin, a low lying area bounded by Flockton and Aylesford Streets, as well as nearby areas affected by similar flooding issues.

The field study and subsequent analysis determined that Dudley Creek contains the following numbers of houses in each level of vulnerability. Note that these figures are current up to 30 June 2014 and reflect the best information available up to that date.

18.1 Flooding history

Figure 24 Flockton flooding in March 2014 event

The Dudley Creek catchment has a history of flooding and floods have been documented across the area dating back to the early 1900's. The area was regularly flooded up to the 1970's, until the Upper

and Lower Dudley Creek Diversions were constructed. It is likely for this reason that no significant flooding of the area has been reported (until the earthquakes) by residents some of whom have lived in the area for 30 years. After the earthquakes, there have been several floods in the area:

- August 2012
- June 2013
- March 2014
- 18 & 30 April 2014

In the March 2014 event over 80 houses were flooded above floor level. For the wider area, the majority of properties experienced flooding across the section or under foundations. Vehicles were also flooded and suffered damage.

Flooding in the Dudley Creek catchment is a result of under capacity waterways which restrict flows and back up in heavy rainfall. The catchment has suffered from significant settlement and there has been a loss in grade from the upper catchment to its confluence with the Avon. The waterways specifically have suffered from lateral spreading and bed heave further worsening the loss of capacity.

The Flockton Basin has specific flooding issues linked to its low lying topography (Figure 25), the area drains to the Flockton Invert to the south, which is a pipe that runs west to east across Harrison Street to Dudley Creek. The pipe remains partially full at all times and when Dudley Creek is in flood it loses functionality and suffers from the backflow of fluvial water. The drain is hydraulically linked to Dudley Creek and Mairehau Drain, over time water levels in the area equalise with those in the stream. This is accelerated by water spilling out of Mairehau Drain, flooding from this mechanism compounds the ponding in the area. The depth of the water resulting from this ponding is known to flood many houses above floor level.

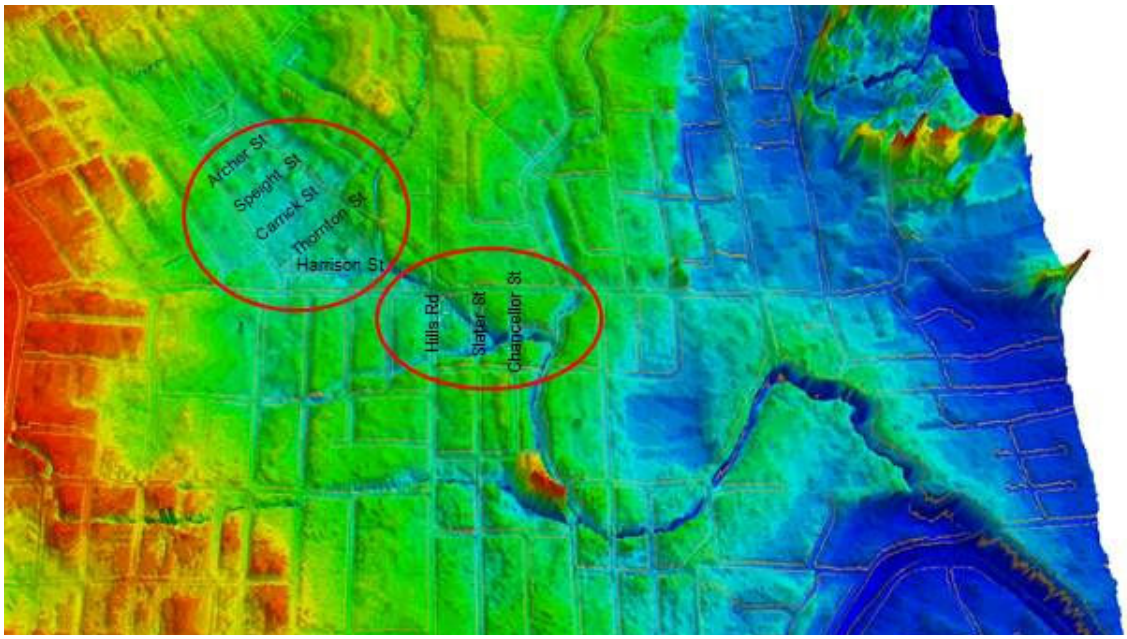


Figure 25 LiDAR image of the Dudley Creek catchment showing the low points (blue is the lowest, green slightly higher, and orange the highest level)

Across Dudley Creek and its tributaries, high water levels in the waterways incurred through a loss of capacity has a direct impact on the ability of drainage infrastructure to discharge, leading to widespread pluvial flooding.

The Dudley Creek catchment including the Flockton area has been extensively studied by Council under the Land Drainage Recovery Programme. This resulted in a feasibility assessment of the long-term preferred solutions for managing flood risk in the area. The options identified are currently being reviewed by Council.

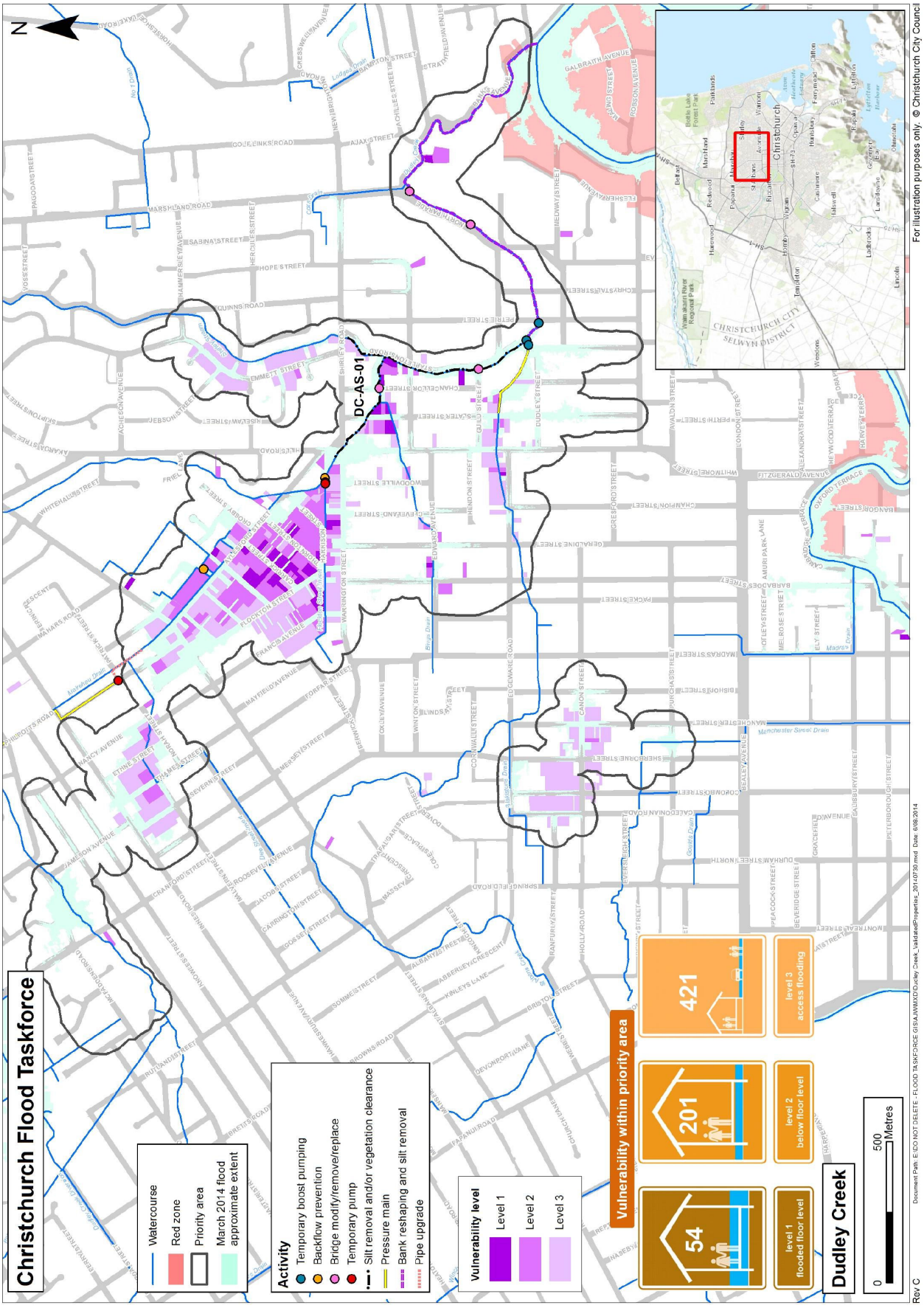


Figure 26 Dudley Creek priority area and proposed works

18.2 Field studies

Field visits were undertaken in May and June 2014 to better understand the flooding issues experienced. Properties which were known to be affected were visited by staff who recorded flooding information.

After the June 2013 and March 2014 flood events, the area was also surveyed. This included house surveys, flood level surveys and extent mapping.

As part of the Taskforce, a site walkover was conducted which in conjunction with the existing knowledge of the area was used to identify options for temporary flood mitigation.

Other field studies were completed as part of the Dudley Creek permanent options identification and feasibility studies.

18.3 Community engagement

18.3.1 Community meetings

Dudley Creek information evenings were held in March 2014 to discuss the two long term engineering options. Feedback from the community was that they welcomed the flood remediation but were concerned by the timeframe for implementation (approximately 2-3 years).

A public focus group was held by Council to discuss the temporary options which are being explored. It became apparent that residents were open to large scale pumping if it relieves flooding. The group was also asked whether they would accept the noise resulting from pumping during flood events, and the group responded favorably to the question.

The public focus group indicated they did not see sand bags as an option, but were open to house tanking. The idea of temporarily raising houses raised concerns over resilience during any future earthquakes.

The Taskforce held a public meeting with the community at Edgeware Bowls Club on 3 June 2014, and the temporary flood mitigation measures identified in this report were presented and discussed.

Meetings to discuss specific components of the Taskforce's proposals with affected property owners have also been held or are planned for the coming weeks. The first meeting was held at the Chancellor Street culvert to discuss its removal on 25 June 2014 following a letter drop. A meeting has also taken place for the Tay Street Drain Pump Station with Kensington Avenue property owners.

18.3.2 Resident surveys

Across the Dudley Creek catchment 192 households have completed a survey questionnaire or provided data which was subsequently entered into it. The data provided details of the individual property owner's experience of flooding since the earthquakes.

18.3.3 Other engagement

Engagement of individual property owners has been ongoing throughout the Taskforce, and this has included discussions held to identify and validate flooding but extends to discussions relating to the impacts of Taskforce and permanent solution proposals.

Where access to land or its acquisition for channel improvements has been required property owners have been directly engaged, and these discussions are ongoing.

Discussions have been held with Arrow Consulting, who are the project management organisation for Southern Response. These discussions, which are ongoing, seek to remove obstructions caused by private bridge assets, particularly those which impose increased obstructions since the earthquakes.

18.3.4 Key issues identified by the community

Fundamentally the community wants to see action from the Council to address the flood risk. Whilst proposals have been positively received it is understood that the proposals are temporary fixes that

will not address severe flood events or the long term flood risk. For this reason the public are keen to see a decision on the permanent approach to resolving the flood risk and furthermore to works happening on the ground.

A number of property owners in the catchment have identified their need to rebuild and in some cases there are insurance complications or time constraints. Not all have the confidence to rebuild without a clear indication of how much flood risk has reduced or how they would be affected by the permanent flood defence solutions.

There has been widespread concern in this catchment and across the city over wastewater overflows and contamination of flood water. It was identified to the community that further studies are underway on how to manage this issue but that it was difficult given the scale of the flood waters in relation to the capacity of the wastewater network. Further community engagement on this issue would be beneficial.

A number of property owners identified specific issues relating to their property, and it is apparent that ongoing support to property owners will be required, particularly until there is further definition of the permanent solutions.

Health issues have been identified by property owners affected by the flooding and this raises concerns over remaining in their homes.

18.3.5 Social impact

Flooding in the Dudley Creek catchment has caused great stress to the residents, many have moved out of their homes for this reason.

Reports in the media have also cited that some residents are unable to sleep when it rains.

Financial stress is experienced by those with increases in insurance excesses (e.g. excesses of $10,000 for flood damage) and those which have left their homes and are now paying mortgages, rates and rents at more than one property. Whilst insurance organisations have covered the costs of temporary accommodation in some cases, it is in all cases time bound and for some this has now been exhausted.

18.3.6 Response required

The Council needs to maintain regular communication with the community, and it is important that progress is reported and reasons for any delays made clear. The community also needs to be engaged on the works going forward, including both those currently at risk of flooding and those affected by the works. In some cases the works are not in areas where properties are at risk of flooding.

The community should be kept informed of wastewater contamination issues and the risks of contact with flood waters. During previous flood events there have been examples of children playing in flood water and others walking through it. Information on what Council can and will do to address contamination needs to be circulated.

18.4 Short-term flood defence recommendations

This section contains a summary of the recommendations for the Dudley Creek catchment. The full range of options considered, key assumptions, gaps and constraints, as well as costs are documented in the appendices.

Note that the local area scheme and maintenance proposals below **do not** provide flood defence to all properties currently affected by regular flooding. There are 10 Level 1 and 164Level 2 houses which remain at risk of regular flooding. Flooding of some of these Level 1 houses will not be resolved by the proposed long-term measures and relocation is likely the only means to protect them.

18.4.1 Local area schemes

There is one local area scheme proposed for the Dudley Creek area (reference DC-AS-01), which is a package of works spanning St Albans and Richmond. The works are complimentary, may have interdependencies and are to be implemented in conjunction with each other.

Initial modelling indicates that the works will have the following effects on the numbers of vulnerable houses. In the more frequent 10 year average return interval events, there will be a significant reduction in post-earthquake floor levels flooded, but the number of flooded floor levels remains **above** pre-earthquake levels. There is no improvement to the numbers of flooded floor levels in the 50 year event.

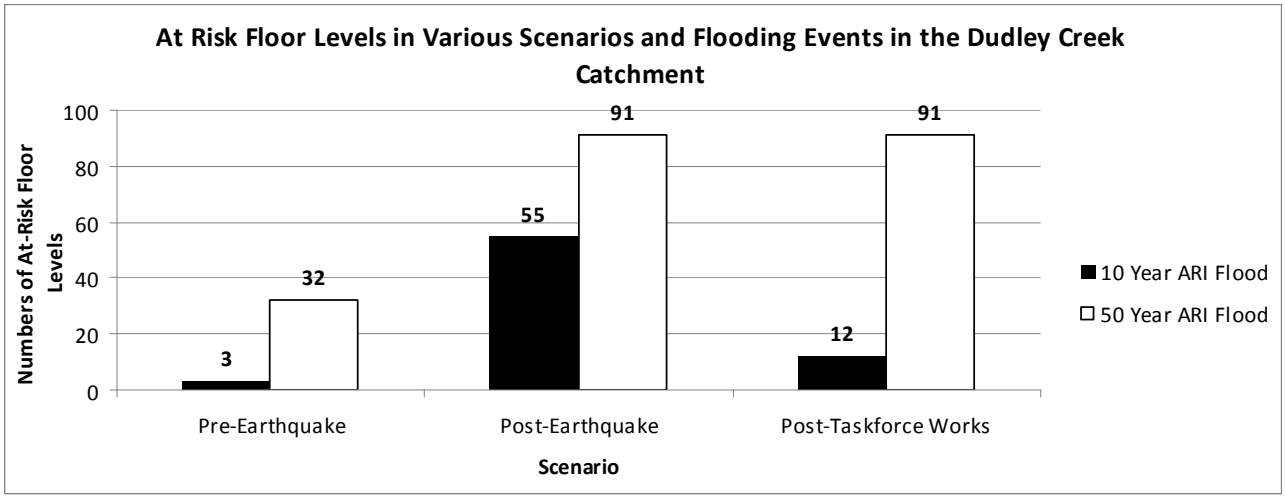


Figure 27 Effect of Taskforce works on vulnerability in Dudley Creek

DC-AS-1.1 Tay Street Drain (Kensington Avenue) Pump Station 202

Description:	Installation of a pump station to divert flood flows from Tay Street Drain and Mairehau Drain to the Lower Dudley Creek Diversion. This will result in a partial beheading of the catchment leading to reduced flood flows being discharged into the downstream network. The pump station will reduce frequent flooding and the flood extents during the 1 in 10 year flood will be reduced as will residual flooding depths.
Confidence level:	Medium - The extraction of 1.5 - 2 cumecs from the system will reduce but not prevent flooding. The feasibility of pumping to the Dudley Diversion has been assessed and it is considered viable, though the capacity of the Dudley Diversion pipeline may limit the pumping from the Tay St Drain depending on antecedent events and the spatial distribution of rainfall/flooding. Further work is being done to quantify the limits of pumping into the diversion pipeline and establish a monitoring/control regime to manage the pumping rate. Operation of the pump station could be made more effective with a change in the operating regime of PS219 and the Cranford Basin which needs further study and discussion with affected parties.
Design stage:	Detailed design

A feasibility report for the Tay Street drain pump station has previously been provided to Council.

DC-AS-1.2 Dudley Creek Channel Improvements and Constraint Removal

Description: Minor channel widening, lowering and vegetation clearance through the lower Dudley Creek between North Parade and Banks Avenue, with additional localised widening upstream. Silt removal between Hills Road and North Parade. These works will increase the sectional area of the channel and will improve conveyance, beyond what is considered the existing maintained capacity of the channel.

The channel works will ease conveyance through the channel and provide area wide improvements benefitting the entire Dudley Creek catchment. The effects, whilst real are not readily quantifiable without hydraulic modelling.

Confidence level: High - A good knowledge of the hydraulics is established for Dudley Creek and its tributaries.

Design stage: Implementation

DC-AS-1.3 Flockton Invert Backflow Prevention and Overpumping

Description: The Flockton area is low-lying and during rainfall, water levels rise within this sub-catchment to match the water level in the Mairehau Drain. In significant rain events, the level of the Mairehau Drain rises to an extent that on-property and above-floor flooding can occur. At the point the Mairehau Drain over-tops, water depth within the sub-catchment can be as deep as 700mm. Installation of a backflow device on the Flockton Invert will prevent the Mairehau Drain flowing into this area. The use of temporary overpumping is required to pump direct rainfall within the sub-catchment into the Mairehau Drain. The overpumping capacity required is dependent upon the desired level of protection. A nominal overpumping capacity of 500 L/s is proposed until such time as revised hydraulic modelling of all implemented temporary flood risk reduction measures is completed and a more accurate discharge capacity determined.

Confidence level: High - The system has been tested and functions as required

Design stage: Implementation

DC-AS-1.4 Boost Pumping

Description: Temporary pumping at culverts to improve conveyance - Pumps fitted with reducer nozzles on outlet pipework to form a jet of water that are then directed downstream through the system to increase system energy resulting in higher velocities and greater discharge

Confidence level: Medium - hydraulic principles have a high degree of certainty, site testing is required to validate theory

Design stage: Preliminary

DC-AS-1.5 Chancellor Street Culvert and Guild Street Footbridge Removal

Description: Removal of the Chancellor Street culvert and Guild Street footbridge which are constraints on conveyance

Confidence level: High - culverts are undersized and have been observed on site during flood conditions to obstruct flow and affect the conveyance.

Design stage: Implementation

DC-AS-1.6 Westminster Drain Backflow Prevention

Description: Installation of localised backflow prevention on local drains connecting to Westminster Drain directly upstream of the Mairehau Drain confluence.

The flood mechanisms associated with the local drainage network reported to worsen flooding at 2 properties will be at managed.

Confidence level: Medium - Local flood mechanism has not been observed first-hand. Proposals based on property owner feedback.

Design stage: Concept

DC-AS-1.7 Bridge Removal and Replacement

Description: Demolition and temporary replacement of 2 private access bridges. The bridges are in a very poor condition, currently obstruct flow and if failed could form significant obstructions in the channel leading to significantly increased flood risk.

Confidence level: High - Existing bridges constrict the channel and there is high risk of the bridge failing and causing blockage, replacement would reduce risk.

Design stage: Concept

DC-AS-1.8 Hydraulic Model Update

Description:	Update hydraulic model to estabish expected hydraulic performance once channel widening, culvert removal and Tay Street Drain pump station are implemented, enabling review of catchment upgrade options 1 and 2 to take account of benefits achieved.
Confidence level:	Medium
Design stage:	Concept

18.4.2 Maintenance

The works identified in the local area scheme could also be considered maintenance; in particular the channel works which seek to manage vegetation and channel geometry. On-going maintenance of the channel will be required to maintain channel capacity, in particular it has been noted that silt deposition in the channel continues to be a problem and that following extensive silt clearance in 2013 further deposition continues to occur.

18.4.3 House defence

As stated above, there are 10 Level 1 and 164 Level 2 properties which **are not** protected by the local area and maintenance schemes proposed above. In the short-term (and in the long-term for some houses) individual house defence, including relocation for some, is the only way of providing flood defence.

Measures for house defence across the Dudley Creek have been investigated and options include house tanking, house raising, bunding and relocation. At this time the specific house defence measures and houses to be protected have not been defined, nor have the funding responsibilities. These all warrant further investigation.

It is currently proposed to review what the requirements for house defence are following a trial of house wrapping and bunding techniques.

18.5 Long-term flood defence recommendations

Long-term solutions are generally outside the scope of the Taskforce. However, the Dudley Creek catchment was previously the subject of a feasibility assessment for two permanent solutions. Consideration has been given to the pathway to implementing either of these long term solutions, to ensure that the temporary solutions are complementary.

18.6 Work completed to date

Works across the Dudley Creek catchment have commenced. Channel widening and lowering has been completed.

A proposal to construct the Kensington Avenue (Tay Street Drain) Pump Station 202 (PS202) was put to Council on 5 June 2014 and a motion for its approval was subsequently approved. The design and construction of the pump station is currently being progressed under the management of Council. The pump station is expected to be constructed within four months. The pump station is designed to remove water from Mairehau Drain and Tay Street Drain.

Channel improvements and constraint removal are well underway with site works having commenced during the first phase of the Taskforce. Approximately two thirds of the proposed works are now complete. As part of the improvements, the channel is being enlarged through widening, silt removal and vegetation clearance. Vegetation clearance, particularly tree removal is being completed with arborist consultation.

The Flockton Invert backflow prevention and overpumping measure has been tested during a high rainfall event. A timber knife gate has been installed and successfully prevents backflow from Dudley

Creek. Permanent access points into the top of the Flockton Invert pipe have been broken out to form suction points for the temporary pumping.

The Guild Street footbridge has now been removed and a temporary timber footbridge is due to be installed imminently. The Chancellor Street culvert is due to be removed as soon as the route is no longer required under a SCIRT traffic management plan for works on Shirley Road. The removal of these constraints on the network will provide improvements to conveyance.

Preliminary testing of the boost pumping concept has been completed and indicates there is merit in pursuing further testing and development.

Other measures to improve conveyance have also been progressed and further investigations of potential bridge removals or temporary replacements have been completed. This confirms where there are constraints in the network and how they can be addressed. Planning and investigations for these measures is underway.

There may be some residual houses in the Dudley Creek catchment which need individual house defence measures. Site investigations have begun to better understand the feasibility of the proposals.

Figure 28 Maintenance works on Dudley Creek to increase channel capacity

18.7 Further work

The local area scheme proposed for the Dudley Creek catchment has a number of components that are currently progressing as individual projects. Specific programmes for these components have been defined.

A key catchment level task is to establish the combined effect of all the components of the scheme. It is anticipated that the combination of works proposed will significantly reduce flood risk during frequent flood events, but the benefit cannot at this time be quantified until the channel is surveyed and the hydraulic model updated. The other components of the option should also be factored into the model to determine the impact on flood risk. The temporary measures are not an alternative to implementing a permanent solution.

Depending on the effectiveness of the temporary solutions, house level defence measures may need to be considered. This can be completed following the revised flood risk assessment and measures implemented as required. At this stage house defence measures are yet to be trialled, the outcome of these trials may dictate which if any house defence measures are implemented.

The Tay Street Drain (Kensington Avenue) Pump Station (PS202) design and implementation is currently underway and is proceeding in accordance with an agreed programme.

The Guild Street footbridge is currently being removed and the reinstatement of the temporary footbridge will take place imminently. The Chancellor Street culvert is to be removed once adjacent SCIRT works on Shirley Road are completed and the road is no longer required for diversion purposes.

The removal and replacement of two private bridges is currently under discussion. These discussions are to be continued in conjunction with the Council operations team to determine whether a mutually beneficial solution can be reached.

The Dudley Creek operational response plan for pumping operations is currently in development. The response plan will inform the change to the maintenance contract.

The use of boost pumps is still being trialled, further testing is necessary in order to determine whether effective benefits can be achieved to justify continued use. As part of this flow monitoring will need to be installed. If the testing proves successful, boost pumping should be integrated into the operational response plan for the catchment.

Channel works through Dudley Creek, Shirley Stream and St Albans Creek are ongoing. Further consultation with property owners is required to discuss vegetation clearance and potential land impacts. This should be led by Council property department in conjunction with operations and design staff.

Ongoing communication with affected property owners is recommended to allow them to progress with their rebuild proposals and to ensure any conflicts with the temporary or permanent works are identified and addressed.

19 Lower Avon

The Lower Avon priority area is shown on Figure 30. The Taskforce has identified that Lower Avon contains the following numbers of houses in each level of vulnerability. Note that these figures are current up to 30 June 2014, and will change as more information becomes available. These numbers also exclude properties within the residential red zone.

19.1 Flooding history

The Avon priority area is shown on Figure 30. The Avon River area is known to be susceptible to flooding and is part of the Christchurch City Council's Flood Management Area. During major events such as the 1992 snow storm, the river has over topped its banks leading to progressively higher and longer stop bank construction. Recent flooding has occurred due to bank overtopping in periods of high rainfall and/or tides, but also due to inability of the local stormwater network to drain to the river. The Canterbury earthquake sequence caused significant land damage near the river and many of the flood prone properties have since been red zoned.

Figure 29 Ponding on Avondale Drive June 2013 (left) and Avon River flooding March 2014 (right)

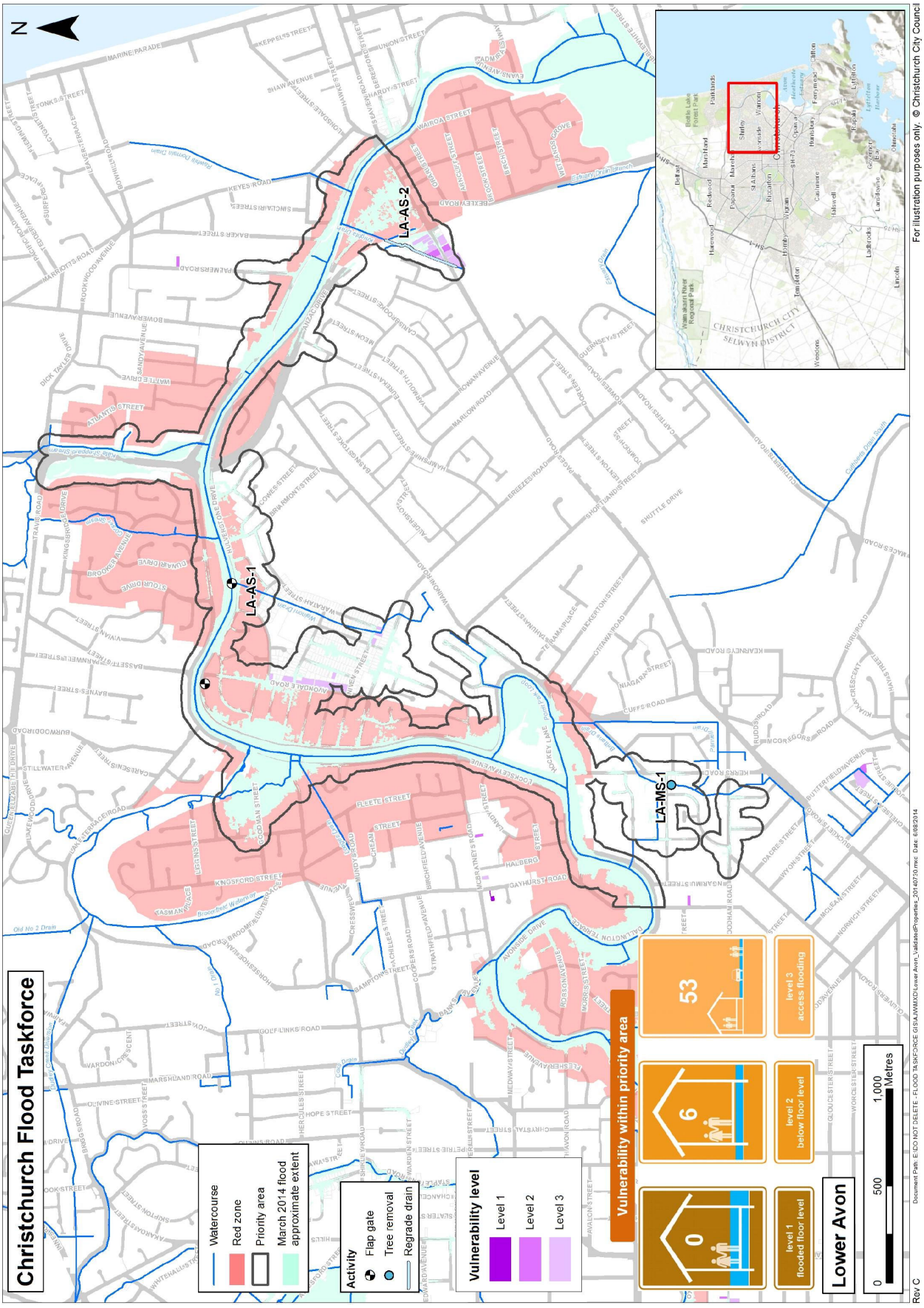


Figure 30 Avon priority area and proposed works

19.2 Field studies

Field surveys were undertaken following the 5 March 2014 event to establish the indicative flood level and extent. The Taskforce has undertaken subsequent field visits to better understand the flooding issues experienced since the earthquakes. This targeted residential green zone areas where the previous survey identified a threat to or flooding of habitable floors, or where residents had identified flooding issues through the survey or at community meetings. These areas were clustered around:

- Brittans Drain
- Avondale
- Knights Drain
- Dallington
- Pamela Street Drain

Ongoing assessment has been made of the Avon River stopbanks since the Canterbury Earthquake sequence. The stopbank was assessed after the March 2014 event, with key areas re-assessed as part of the Taskforce work.

19.3 Community engagement

19.3.1 Community meetings

The Lower Avon community meeting was held on Wednesday 11 June 2014 at the Wainoni Methodist Church. Engineers presented findings from field investigations and answered questions from affected residents.

Residents identified areas of additional flooding around McBratneys Road and the Green Zone area of Dallington.

Residents in the Avondale area near Niven Street and Woolley Street reported issues flushing toilets during high tide events and during flooding. This has highlighted a network issue within the Pump Station 54 catchment. Residents highlighted manhole lids popping in flood events with wastewater/stormwater flows bubbling out of the manholes on Warratah Street.

Residents with pressure sewer systems were concerned about the operation of the systems during and after flooding events.

Isolated property flooding issues were also identified and have been recommended to Council for investigation.

Residents highlighted the lack of clarity between the Council flood management areas and EQC increased flooding vulnerability areas.

19.3.2 Resident surveys

A total number of 11 properties completed a questionnaire on flooding issues relating to their property.

In addition validation teams spoke to a number of property owners to confirm the extent of flooding issues while they were on site.

19.3.3 Key issues identified by the community

Key issues identified by the community were:

- Tidal backflow from the Avon River (Avondale and Dallington areas)
- Inability to flush toilets during flooding and high tide events (Avondale)

- Overtopping of the Avon River stopbanks
- Wastewater manholes overflowing into the streets

19.3.4 Response required

Tidal Backflow from the river requires investigation by Council in the following areas:

- 1350 mm diameter gravity outlet at Pump Station 220 on Hulverstone Drive
- 600 mm diameter stormwater outlet on Locksley Avenue serving McBratneys Road
- 600 mm diameter stormwater outlet on Breezes Road

Wastewater overflow and flushing requires investigation by Council in the following areas:

- Avondale around Warratah Street and Niven Street

Check Pamela Street Drain function.

19.4 Short-term flood defence recommendations

This section contains a summary of the recommendations for Lower Avon. The full range of options considered, key assumptions, gaps and constraints, as well as costs are documented in the appendices.

19.4.1 Maintenance

Planned Maintenance - Lower Avon - Brittans Area (LA-MS-1)

Description:	Immediate removal of a large tree blocking Brittans Drain would relieve the foundation level flooding experienced.
Confidence level:	High - The tree stump was clearly obstructing the flow in the stream. Removal will improve capacity and flow in the drain to the rear of 103 Kerrs Road.
Details:	Works have now been completed under existing maintenance contracts.

19.4.2 House defence

There were no houses identified as needing individual house defence in Lower Avon.

19.4.3 Local area schemes

Lower Avon Avondale Area (LA-AS-1)

Description:	Flap Gates are required at PS220 to prevent backflow into the Avondale Catchment. The existing flapgate is currently broken and needs replaced with a WaStop or Tideflex type backflow prevention. Another flapgate is being installed on the DN600 outfall on Avondale Road by SCIRT.
Confidence level:	Medium - These maintenance works will provide capacity in the network
Details:	Install Flap gate at PS220. PS220 flap gate is currently wedged open, a new flap gate is required to seal the stormwater system and prevent river and tidal backflow into the stormwater network SCIRT to install flapgate on the DN600 outfall on Avondale Road by SCIRT.

Lower Avon - Knights Drain (LA-AS-2)

Description:	Re-grading of Knights Drain required from Pages Road to Anzac Drive.
Confidence level:	Medium - The re-grading will help improve flow in the drain, new stormwater infrastructure is required from SCIRT to get water to the drain.
Details:	Removal of vegetation is within the existing maintenance contract for the drain. Removal of silt and re-grading of the drain requires a specific work request from Council. Works to include removal of high points in the drain and re-grading from Pages Road falling to Anzac Drive. The drain channel will be a straight line in the first instance. The drain's condition and maintenance procedures will be reviewed as a project under the Land Drainage Recovery Programme.

19.5 Work completed to date

Public meetings have been held to discuss the flooding issues and recommendations for the Lower Avon.

Multiple site visits have been undertaken with residents to discuss flooding issues. Field validation has occurred in existing areas and others identified areas of concern.

Investigation into the 1350 mm diameter stormwater outfall on Hulverstone Drive is already underway. Council are identifying possible solutions to the issues and are progressing in alignment with SCIRT works in the area.

Tree removal was undertaken in the Brittans Drain which will reduce flooding on the back of properties on Kerrs Road.

Figure 31 Brittans Drain before removal of tree (left) and after (right)

SCIRT works are being undertaken on the Avondale Road to install a flapgate on the 600 mm diameter outfall serving the Avondale Road green zone residents.

20 Heathcote Valley

The Heathcote Valley priority area is shown on Figure 33. The field study and subsequent analysis determined that Heathcote Valley contains the following numbers of houses in each level of vulnerability. Note that these figures are current up to June 30th 2014 and reflect the best information available up to that date.

20.1 Flooding history

During significant rainfall events flooding has occurred around the lower lying properties of Pawaho Place and Stedley Place from two sources.

Firstly when water flowing along Bridal Path timbered drain adjacent to the properties breaches the timbering and back flows along the outfall pipes serving the area.

Secondly when there have been blockages in the upstream network at critical inlet structures sites. Water has spilt over and flowed along the roading network to Martindales Road and into Pawaho Place.

Figure 32 Truscotts Road – Deavoll Place – showing subsidence of timbered drain

In 2014, flooding occurred on 5th March, 18th and 29th April. The March event resulted in flooding of 10 buildings above the floor level, 2 properties above the garage level, and 43 properties up to the foundations.

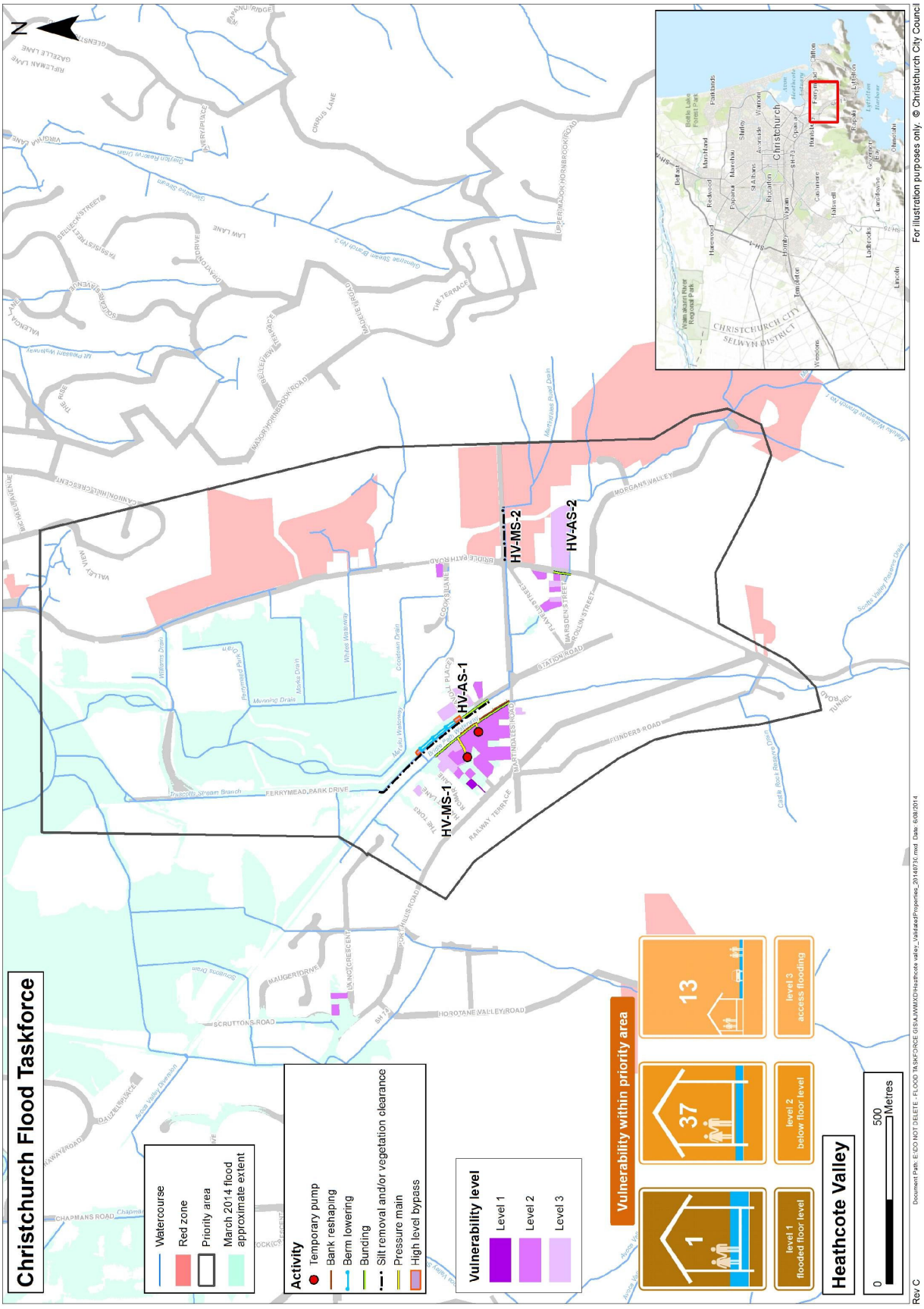


Figure 33 Heathcote Valley priority area and proposed works

20.2 Field studies

Field visits were undertaken in May and June 2014 to better understand the flooding issues experienced. A number of areas known to flood were visited and issues identified.

20.3 Community engagement

20.3.1 Community meetings

The community meeting was held on Thursday 12th June at the St Marys Anglican Church Hall. There were approximately 80 residents present to listen to the findings and recommended local schemes to be put in place.

20.3.2 Resident surveys

There have been 40 questionnaire responses received for this area.

20.3.3 Other engagement

Met with individual property owners to confirm where water flowed through properties as a result of the water not being contained within the stormwater network.

20.3.4 Key issues identified by the community

Key issues of concern for the community were:

- Stormwater not being contained within the network due to blockages and under capacity in parts of the system. The water then flows along carriageways and on to the lower lying properties along various streets.
- Under capacity of sump inlets, particularly on Martindales, Bridle Path and Port Hills Roads.
- Contamination from a surcharged sewer system.

The work being carried out on the former Maltworks site and how on site surface water is currently controlled and on site stormwater is to be controlled when the development has been completed.

Maintenance with regard to silt removal from the open drains and piped network.

20.4 Short-term flood defence recommendations

This section contains a summary of the recommendations for Heathcote Valley. The full range of options considered, key assumptions, gaps and constraints, as well as costs are documented in the appendices.

20.4.1 Maintenance

Removal of sediment from Truscotts Road timbered drain - Martindales Road to the downstream bend along Truscotts Road. A request has been put in for this work to be carried out (HV-MS-1).

Vegetation and silt removal along with bank works along Martindales Road drain. Task order for this work is in place and work is due to start first week of July (HV-MS-2).

20.4.2 House defence

There are no house defence proposals for this area.

20.4.3 Local area schemes

HV-AS-01 Heathcote Valley Area Scheme 1
A combination of in channel works and works within the road corridor.

Truscotts Road Timbering

Description:	Raise height of timbering on carriageway side of existing timbered drain and bund adjacent to contain water within timbered drain to a point downstream of Deavoll Lane
Confidence level:	High
Design stage:	Detailed

Truscotts Road - High Level By-pass

Description:	Construct two high level by-pass areas on Truscotts Road to allow water to flow across the carriageway and berms from the timbered drain to the branch of the Matuku Waterway.
Confidence level:	High
Design stage:	Detailed

Pawaho and Stedley Place

Description:	Raise height of timbering on property side of timbered drain from Martindales Road for 300 m downstream to towards DN1200 brick barrel culvert. This to stop water overtopping the drain and flowing on to adjacent properties.
Confidence level:	High
Design stage:	Detailed

HV-AS-02 Heathcote Valley Area Scheme 2
A short bund forming an elevated section of road.

Marsden Road - Bridle Path Road Intersection

Description:	Bunding across end of Marsden Road at the Bridle Path Road intersection
Confidence level:	High
Design Stage:	Feasibility/detailed

20.5 Work completed to date

The Heathcote Valley catchment identified one Vulnerability Level 1 and eleven Vulnerability Level 2 properties.

The Taskforce recommended maintenance works to ensure that critical inlet and outlet sites to be inspected. This has been carried out and it has been confirmed that these sites are inspected prior, during and after each storm event. The piped network in Martindales Road has been cleaned of silt as well.

Removal of silt from the timbered section of Bridle Path Drain along the west side of the railway embankment over a length of 300m has been completed to increase the capacity of this section of the network. Cut off channels have been put in place on the former Maltworks site to divert site flow into the open water channel on this site.

The contract for the diversion of flow to the east side of the railway embankment has been let which will be completed in 2 – 3 months.

20.6 Options for investigation or future work (not costed)

Larger capital works:

- Bridle Path Waterway inlet structure at 25 Port Hills Road - New inlet structure with increased grill area (at least 10 times DN1600 pipe area).
- Diversion of the flow from Truscotts Road drain across to Matuku Waterway by means of two twin DN375 piped bubble up systems, one set located at the start of Deavoll Place and the other opposite the brick barrel connection under the railway embankment.
- The priority of the next stage of the Matuku Waterway (Morgans Valley) may need to be reassessed. Currently this waterway discharges into Heathcote Valley Drain and then into a network of DN750, DN900 pipes and open channel that is under capacity.
- A DN1600 pipe was laid out into Bridle Path Road for later extension up and into section 112R Bridle Path Road. The Council purchased a route through a proposed subdivision prior to the earthquake for the next stage of this work to divert the waterway from Heathcote Valley Drain. This route now lies in red zoned land.
- Option 1 - is to gain approval to access the land to create the 400m open waterway and extend the DN1600 approximately 65m to connect with the downstream end of the waterway.
- Option 2 – extend the DN1600 pipe approximately 380m along Bridle Path Road to Heathcote Valley Drain. Then either increase the capacity of approximately 210m of existing drain or pipe this section and install an inlet structure.
- The next stage of the diversion of Bridle Path Waterway is to extend the culvert approximately 80m downstream from the manhole at Martindales Road and increase the capacity of the timbered drain for approximately 75m to downstream of Deavoll Place.
- Install two additional DN750 pipes across Ferrymead Park Drive to provide additional outfall capacity from the detention basin to saltmarsh pond.
- Install permanent tide gate at the outlet of the Saltmarsh pond.

Maintenance:

- Review frequency of inspection of silt build-up in of the DN675 pipe in Martindales Road. This may require more frequent inspections initially to determine which storm events result in excessive silt built-up, and then to adjust the maintenance regime accordingly.
- Truscotts Road timber drain – frequency of monitoring of silt build up should be reviewed as this section of drain will be the main conduit for the catchment when the diversion under the railway overbridge is complete. There should be six boards showing for maximum capacity and to keep water from overtopping the timbering.

Figure 34 Stedley Place during March 2014 event

21 Upper Heathcote

The Upper Heathcote priority area is shown on Figure 35. The field study and subsequent analysis determined that Upper Heathcote contains the following numbers of houses in each level of vulnerability. Note that these figures are current up to 30 June 2014 and reflect the best information available up to that date.

21.1 Flooding history

The Upper Heathcote priority area is shown on Figure 35, and encompasses Weir Place cul-de-sac and Smartlee Street. Residents report a history of flooding that predates the earthquakes. However, there is a perceived increase in frequency following the earthquakes, with flooding across sections and into Weir Place on approximately six occasions.

21.2 Field studies

Field visits were undertaken in May and June 2014 to better understand the flooding issues.

21.3 Community engagement

21.3.1 Community meetings

The community meeting was held on Tuesday 27 May at Somerfield Primary School Hall. There were approximately 300 residents present to listen to the findings and recommended local schemes.

21.3.2 Resident surveys

In the Upper Heathcote area six households have completed a questionnaire in relation to the flooding they have experienced in this area.

21.3.3 Other engagement

Taskforce engineers met with individual property owners to confirm where water flowed through properties as a result of the water not being contained within the stormwater network.

21.3.4 Key issues identified by the community

The only occurrence of the Heathcote River overtopping its banks and flowing into the head of Weir Place was in the March event. The key issue in other events is the water coming from Smartlea Street into Weir Place and filling the head of the cul-de-sac with a depth of 400-500 mm. There have been a number of cars written off due to flood damage. To protect cars in significant events residents have to park their cars to Smartlea Street.

The current outfall is slow to discharge as it is reliant to the drop in water level in the river. Therefore, the residents would like to see a pump installed to discharge the water at a faster rate.

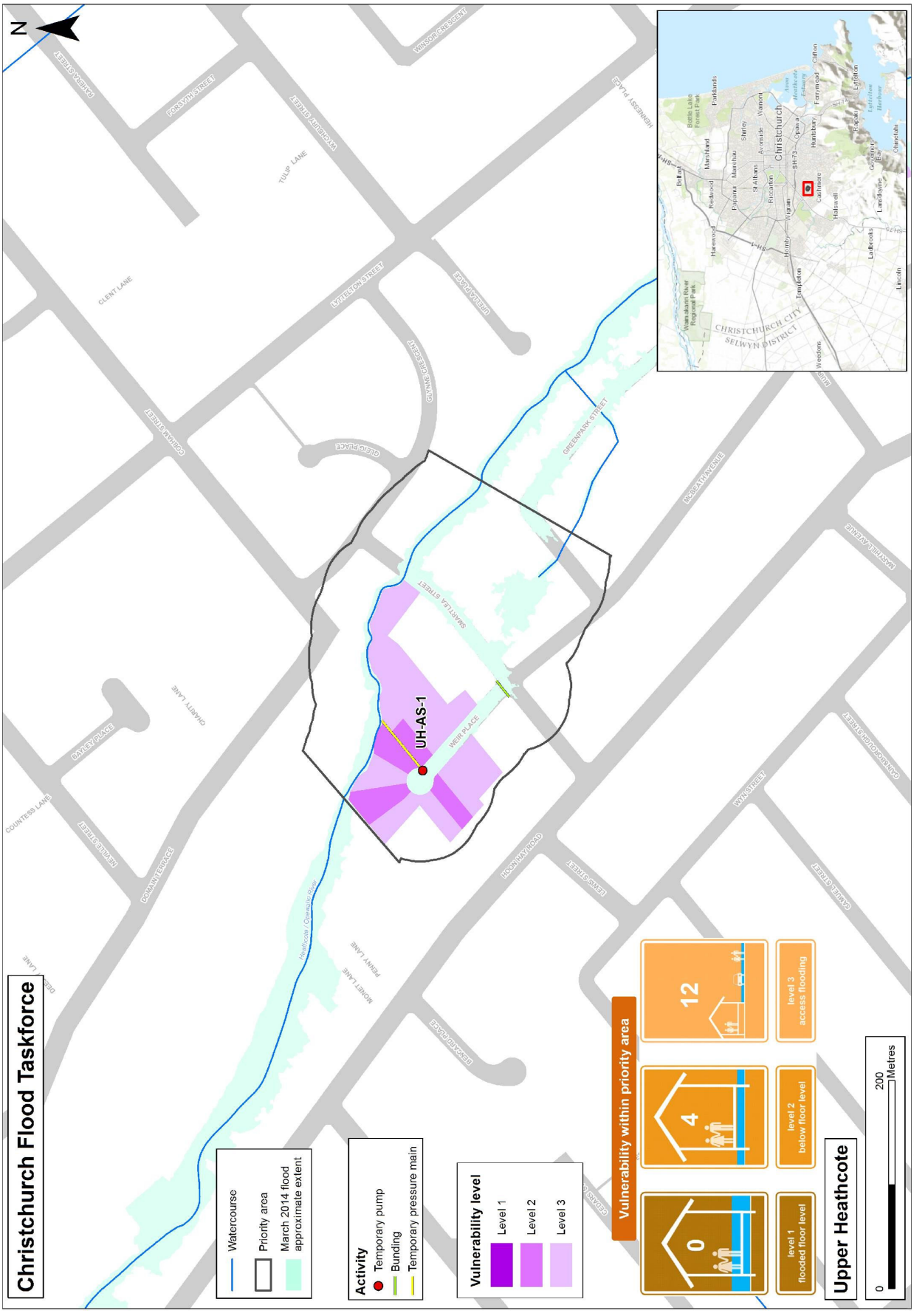


Figure 35 Upper Heathcote priority area and proposed works

21.4 Short-term flood defence recommendations

This section contains a summary of the recommendations for Upper Heathcote. The full range of options considered, key assumptions, gaps and constraints, as well as costs are documented in the appendices.

21.4.1 Maintenance

No maintenance work is required.

21.4.2 House defence

There are no house defence proposals for this area.

21.4.3 Local area schemes

UH-AS-01	**Upper Heathcote Area Scheme 1 – Weir Place**
Description:	A localised bund forming a stopbank with a mobile pump. This includes constructing a bund and a road hump reshaping at the intersection of Smartlea Street. A permanent pump should be considered in the longer term.
Confidence level:	Medium-High. The bunding across Weir place will divert flows across the intersection along Smartlea Street towards the river.
Design Stage	Feasibility

21.5 Work completed to date

Temporary flood defence measures have been identified for the Upper Heathcote area that comprises a local area scheme that will benefit the general area around Weir Place.

Within Upper Heathcote catchment the Taskforce identified no Vulnerability Level 1 and five Vulnerability Level 2 properties.

There have been further reports of properties in outside of the priority area through calls-ins from the public that are yet to be validated.

The public meeting held on the 27th May enabled confirmation of the flooding experienced at the head of Weir Place and identified that there may be an issue with the outfall pipe draining this area.

The Weir Place DN300 outfall pipe has been checked and there are no issues.

21.6 Recommendations for investigation or future work (not costed)

With implementation of the reshaping works at the intersection of Weir Place and Smartlea Street the water levels at the head of cul-de-sac head needs to be monitored in each storm event to determine the need to mobilise a pump to the site ahead of storm events. If it is found that a pump is required for each event then a permanent pump solution should be investigated. Monitoring should be by area manager and permanent pump installation put into the capital expenditure program.

22 Lower Heathcote

The Lower Heathcote priority area is shown on Figure 37. The field study and subsequent analysis determined that the Lower Heathcote contains the following numbers of houses in each level of vulnerability. Note that these figures are current up to 30 June 2014 and reflect the best information available up to that date.

22.1 Flooding history

The Heathcote River Flood Plain Management Strategy (1998) highlights the historic flooding of the Heathcote River. This records flooding of 73 houses above floor level on at least four different occasions (1968, 1975, 1977 and 1980) prior to 1998. The most affected areas were noted as Waimea Terrace, Richardson Terrace, Aynsley Terrace, Clarendon Terrace, Riverlaw Terrace and Eastern Terrace.

Although flooding had previously been experienced a number of residents in the area indicated that there had been no previous flooding on their properties prior to the earthquakes. It is fairly common for some properties in this catchment to experience shallow flooding or have restricted access during large rainstorms.

Figure 36 Lower Heathcote riverside properties - extensive floor level flooding on Riverlaw Terrace

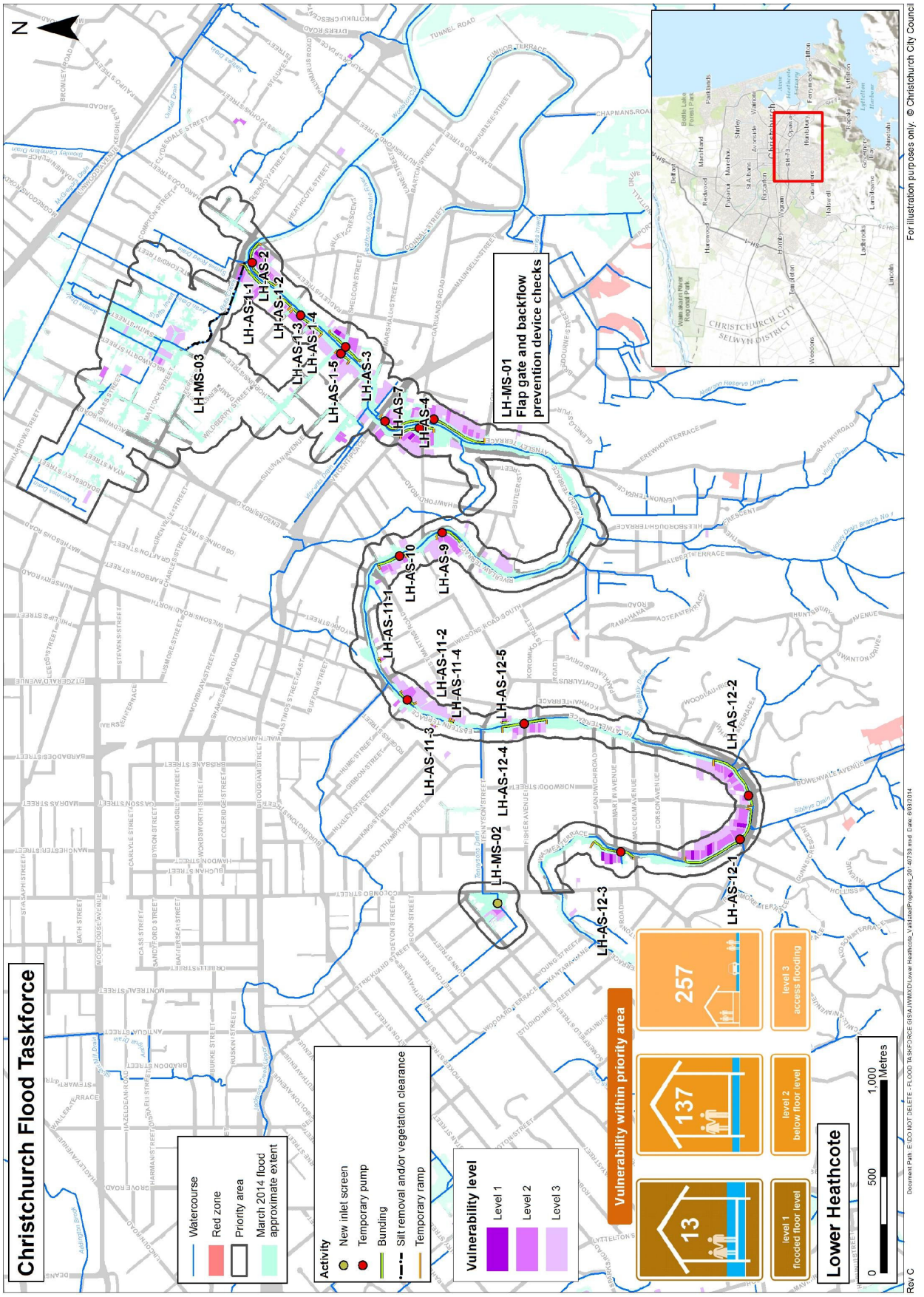


Figure 37 Lower Heathcote priority area and proposed works

Flooding occurred in the Tennyson Drain area in March 2014. This area had not experienced floor level flooding previously. Flooding also occurred in the Bells Creek area. This area is known to have issues after the earthquakes due to drain capacity and changes in topography.

22.2 Field studies

Field visits were undertaken in May and June 2014 to better understand the flooding issues experienced. Areas of known flood risk were visited in addition to areas which had identified above floor level flooding in since March 2014.

22.3 Community engagement

22.3.1 Community meetings

A community meeting was held on 27 May 2014 at Somerfield School. This presented information to the community on the Lower Heathcote flood issues and potential area schemes. It also allowed residents to ask questions of the Taskforce to better understand the issues with their area.

22.3.2 Resident surveys

A total of 117 residents have undertaken the flooding questionnaire.

In addition validation teams spoke to a number of property owners to confirm the extent of flooding issues while they were on site.

22.3.3 Other engagement

In addition to the above community meetings field visits were made to all known vulnerable properties. Residents who were home were spoken to on their flooding experiences and data was collected on flood extent and property type and damage.

Taskforce representatives spent an extensive period of time along the riverside properties consulting with residents who raised issues. Key locations where residents were consulted include Richardson Terrace, Clarendon Terrace, Ford Road, Waimea Terrace, Eastern Terrace and Hunter Terrace.

Residents in the lower reaches highlighted that river backflow during flooding and tidal events as a key concern. Residents around Hunter Terrace highlighted concern on the depth and velocity of the Heathcote River. The majority of residents who access their properties via the riverside road have had multiple access issues due to flooding including a number of residential homes and care facilities.

Residents affected by Tennysons Drain and associated flooding in the Tennyson and Colombo intersection met with Taskforce representatives onsite. Residents highlighted concern that future floods may occur. Taskforce representatives discussed some of the reasons behind flooding in the area and about recommendations for inletting improvements in the Tennysons drain.

Bells Creek residents were consulted on site where they had identified on-property and underfloor flooding issues. The Taskforce highlighted that the Bells Creek catchment was being investigated under the Land Drainage Recovery Programme. Taskforce representatives noted that the drain had recently had maintenance undertaken and that Bells Creek was maintained under existing maintenance contracts.

Additional areas that were identified outside existing schemes have been included in Section 27.

22.3.4 Key issues identified by the community

Key issues identified by the community included:

- Damage to property from flooding
- Insurance issues including lack of cover for flooding and increased excesses
- Temporary relocation due to flooding

- Access issues during flooding periods
- Lack of information associated with what to do before, during and after flooding, including advice on how to protect their homes from flooding

22.3.5 Social impact

Public health issues are raised where wastewater has been seen coming out of gully traps and manholes. This was highlighted in the Clarendon Terrace area where residents perceived this is more prevalent post SCIRT wastewater repairs. It should be noted that most floodwaters have some contaminants.

There was a notable psychological impact from stress of flooding including worrying about future flooding, insurance issues, repairs and living with damp homes. Many residents noted that their properties were damper than usual and required dehumidifiers running regularly.

22.3.6 Response required

- Continue to provide information and communication to residents by email newsletter, community meetings and website.
- Provide advice to residents on what they can do to protect their properties.

22.4 Short-term flood defence recommendations

This section contains a summary of the recommendations for the Lower Heathcote. The full range of options considered, key assumptions, gaps and constraints, as well as costs are documented in the appendices.

22.4.1 Maintenance

LH-MS-01 Planned Maintenance - Lower Heathcote River Backflow Checks

Description:	Flap gates and backflow devices checking and cleaning is required to ensure backflow prevention.
Confidence level:	Medium - These maintenance works are part of a package of works to achieve successful bunding. The resulting impact is not however quantifiable without further investigations.
Details:	Existing flapgates need to be added to the maintenance lists. Surveys have been undertaken and results are being delivered to Council

LH-MS-02 Planned Maintenance - Tennysons Drain Inletting

Description:	Upgrading of the Tennysons Drain Inlet
Confidence level:	Medium - These works will help reduce the risk of blockages in the drain. The drain needs assessed under Asset and Network Planning for the capacity of the existing piped network.
Details:	Upgrade existing inlet, provide access to existing inlet, install new screen.

Implementation

Description:	Works are to be added to the maintenance list and undertaken pre and post events.
Prerequisites & constraints:	Design is to be undertaken for the most suitable inlet including H&S access.

LH-MS-03 Planned Maintenance - Bells Creek

Description:	Removing silt from Bells Creek. Channel works comprising widening, lowering and vegetation clearance are all recommended. Blocked sumps on Randolph and Bass streets need cleared are covered under the maintenance contract.
Confidence level:	Medium - These maintenance works will provide capacity in the network. The Land Drainage Recovery Plan is looking at the catchment for a long term solutions.
Details:	Works have been undertaken to clear sections of Bells Creek. Further work planned.

22.4.2 House defence

No individual houses defence measures are proposed in the Lower Heathcote area.

22.4.3 Local area schemes

Planning issues

The draft Taskforce report proposed stopbanks as a temporary solution for flood protection in riverside properties. Temporary stopbanks need to be considered in the context of long-term planning decisions made by Council. At present there is no long-term solution agreed to for the Lower Heathcote, and temporary stopbanks may need to be in place for a considerable time. It may also make longer term planning measures less effective since a level of protection will be established.

However, temporary stopbanks may also allow Council to provide protection to vulnerable houses along the Lower Heathcote before the long-term strategies are implemented, and this needs to be weighed against any possible negative effects.

As a result of these issues, it is recommended that Asset and Network Planning review this scheme against the long-term options to ensure that the best outcome is achieved for the residents of Lower Heathcote.

Description of proposal

Protection of the most vulnerable properties only would require multiple stopbank locations with a total combined linear length of 3.6km with an additional 1km of bunding to complete cross sections.

Temporary stopbanks are not intended as a permanent solution and are only designed to reduce the impact of regular flooding. Stopbanks do not remove the risk of flooding and will be designed to a height to meet the current Council drainage levels of service. All stopbanks retain the residual risk of overtopping and failure in extreme events.

Installing stopbanks may require temporary or long term traffic management which may include reducing riverside streets to preferential flow with passing bays. Roads and footpaths would be closed in flood events with minimal access to properties.

Stopbank options

Options for temporary stopbanks were assessed based on the cost and the practicality in an emergency response or prior to a flood event. The table below provides a high level evaluation of different methods of stopbanking.

Table 7 – Assessment of stop banking methods

Stopbank Type	Description	Advantages	Disadvantages	Recommendation
A. Fully deployable	These stopbanks would be deployed prior to a flood warning	No visual difference to area in non-flood events.	Lengths required would be impractical to implement in a storm event. High CAPEX and OPEX (Suppliers not likely to hold stock lengths for rental).	Not recommended due to practicalities of deployment and costs.
B. Gravel stopbank (with deployable sections)	Gravel stopbanks would be constructed on the riverbank and would remain as a temporary structure. Deployable sections would be added prior to a flood warning	Quicker response time than Option A. Lower CAPEX than Option A. Temporary section could be rented or purchased.	Visual implications may not be acceptable to residents and river path users. Bare gravel susceptible movement. Requirements monitoring and maintenance	Carried forward for further costing
C. Grassed stopbank (with deployable sections)	Grassed stopbanks would be constructed on the riverbank and would remain as a temporary structure. Deployable sections would be added prior to a flood warning	Quicker response time than Option A. Lower CAPEX than Option A. Temporary section could be rented or purchased. Visually more acceptable than gravel. Opportunity to plant instead of grassing.	Grassed banks would require alternative maintenance due to the slopes required. Require monitoring. Susceptible to erosion prior to grass establishment.	Carried forward for further costing
D. Grassed or gravel stopbank (with semi-permanent ramps)	Grassed or gravel stopbanks would be constructed on the riverbank with drivable ramps at the stopbank height to seal the areas.	Minimal response time required.	Higher CAPEX due to drivable ramps. Possible drainage issues with ramps.	Not recommended due to height and length required for drivable ramps.

*Note the use of the term ‘temporary structure’ is intended to mean until a permanent solution is implemented

Table 8 – Types of deployable stopbanks

Brands	Advantages	Disadvantages	Costs
TigerDam 	Low CAPEX	Requires forklift or Hiab to lift units Labour intensive Time intensive for long lengths	$300-400/m for 0.96m height
WaterGate 	Quick to implement Rapid deployment (self-inflating) Ease of dismantling	High CAPEX	$700-1050/m for 1m height
GeoDesign Barrier 	More robust Visually more secure (from residents perspective)	Very labour intensive High CAPEX Time intensive for long lengths	$600-1500/m for 0.93m height

Due to the nature of flood response, speed and ease of deployment is a priority. For this reason the WaterGate deployable stopbank has been selected as the preferred option.

Stopbank modelling

The Taskforce is currently undertaking modelling to determine the required height for stopbanks and to assess the impact on adjacent properties. Stopbanks only displace floodwater from defined areas; they do not remove it. The volume of water displaced by the stopbank will have an effect on the river height. Individual small isolated areas will have negligible effect on the river height, but collectively the stopbanks on the Heathcote River need to be modelled to determine the combined effect of the displaced floodwaters.

Visual impact of stopbanks

Feedback from residents during public and onsite meetings indicated that stopbank protection was preferable to no protection at all. The overriding priority for residents was the protection of property and assets with the temporary visual appearance of the riverside secondary.

The following concept images show the visual impact of gravel and grassed stopbanks in various stages. The images are a visualisation aid only and do not represent the actual height of stopbanks, impact of flooding or the proposed alignment of stopbanks in these areas.

Figure 38 Concept image of grassed stopbank along river

Figure 39 Concept image of aggregate stopbank along river

Figure 40 Concept image of grassed stopbank before flood

Figure 41 Concept image of flooding protection in an extreme flooding event

Local area scheme details and costs

Costs have been developed as a high level estimate based on a conservative height of 1 m grassed stopbanks. Stopbank heights will vary along the length of the Heathcote River.

Table 9 shows the relative cost savings by reducing the height from 1 m to 0.5 m. It is expected that modelling will reduce the overall cost of temporary stopbanks along the river.

Table 9 – Stopbank Costs (based on 1:2 batters)

Stopbank Type	500mm Height ($/m length)	1000mm Height ($/m length)	% Difference
Aggregate	$70	$220	300%
Grassed	$95	$270	280%
Planted	$140	$340	250%

Table 10 shows the number of properties that benefit per scheme section.

Table 10 – Properties benefited per scheme section

	Properties per scheme		
Scheme ID	**Level 1**	**Level 2**	**Level 3**
LH-AS-1-1	0	8	8
LH-AS-1-2	0	4	2
LH-AS-1-3	0	6	0
LH-AS-1-4	0	3	2
LH-AS-1-5	0	3	6
LH-AS-2	2	10	9
LH-AS-3	2	6	4
LH-AS-4	0	13	21
LH-AS-7	1	10	13
LH-AS-9	0	8	6
LH-AS-10	0	4	7
LH-AS-11-1	0	1	0
LH-AS-11-2	0	1	1
LH-AS-11-3	0	1	0
LH-AS-11-4	0	1	1
LH-AS-12-1	5	27	21
LH-AS-12-2	1	10	9
LH-AS-12-3	2	5	0
LH-AS-12-4	0	5	7
LH-AS-12-5	0	1	2
Total	**13**	**127**	**119**

Temporary stopbank installation details

Description:	Installation of temporary stopbanks on the Heathcote River including traffic management and localised stopbanks in the following locations: • Richardson Terrace to Ferry Road (plan reference. LH-AS-1) • from on Clarendon Tce to Radley Street (plan reference LH-AS-2) • Clarendon Tce (plan refererence LH-AS-3) • Clarendon Tce to Grange Street (Plan ref. LH-AS-4) • Ford Road to Opawa School (Plan ref. LH-AS-7) • Riverlaw Tce to Derrett Place (Plan ref. LH-AS-9). • Derrett Place to Esher Place (Plan ref. LH-AS-10). • Riverlaw Terrace to Waltham Road & Eastern Terrace (plan reference LH-AS-11) • Around Beckenham Loop/Waimea/Hunter/Eastern Terrace (plan reference LH-AS-12)
Confidence level:	Medium- Hydraulic modelling is currently being undertaken to assess the height of stopbank required for the areas. Modelling is also to assess the effect of stopbank on neighbouring properties.
Design stage:	Concept

22.5 Work completed to date

Public meetings and consultation

Public meetings have been held to discuss the flooding issues and recommendations for the Lower Heathcote. Recommendations are being progressed and the river is currently being hydraulically modelled to further assess Taskforce schemes.

Extensive site visits with affected residents and stakeholders has been undertaken in co-ordination with field validation.

Field validation has occurred along the length of the Heathcote and others identified areas of concern. The recommended local area schemes typically consist of stopbank and temporary pumping.

Stopbank optioneering

Assessment of stopbank options and the suitability for each of the areas has been undertaken including consultation with some affected residents. Site walkovers and meetings have been held with the Council Land Drainage Operations team to advise on the practicalities of stopbanking and the effects on traffic flows and bank maintenance.

Hydraulic modelling

Hydraulic modelling has been undertaken to estimate the flood heights for regular flooding. The model is currently being calibrated against the 5 March 2014 storm which has a good sample of data to calibrate actual flooding with flood heights experienced. Once complete the model will run simulations of a 2%ARI and a 10%ARI with the stopbanks simulated to assess the effects of stopbank heights on adjacent properties.

Modelling is also being undertaken to assess the viability and effects of dredging on the Heathcote River. The modelling output will be used to make compare the costs and effects of dredging against other solutions.

Maintenance

Maintenance options identified for the Bells Creek area are being undertaken as part of the maintenance contracts with silt removal being proposed in the report. Site visits for the local area solutions are to progress next week.

Maintenance has been undertaken on a number of streams and on the Heathcote River bank. Council is currently assessing the need to remove raupo and non-native weeds in the river.

Under the existing maintenance contracts a number of areas have had sumps and pipe clearance undertaken in key areas.

Tennysons Drain area has been assessed and recommendations have been made to Council to improve the access to the inlet screen for the Tennysons piped network. Recommendations have also been proposed for a new constructed inlet with a larger screen to help prevent blockages due to detritus.

Backflow prevention

Council has undertaken surveys of all the stormwater outlets on the Heathcote River. The outlet survey will indicate which stormwater outlets have backflow prevention installed and assess the condition of the outlets. This will advise Council of the scale of capital expenditure to install backflow prevention on key outfalls.

Figure 42 Upper Bells Creek – scope to increase channel capacity

22.6 Recommendations for investigation or future work (not costed)

- Modelling for dredging feasibility (currently commissioned by the Taskforce and included in Taskforce costs)
- Modelling for stopbank feasibility (currently commissioned by the Taskforce and included in Taskforce costs)
- Flapgate and backflow prevention inspection and installation – Land Drainage Operations Team
- Vegetation removal from the Heathcote River – Land Drainage Operations Team

23 Southshore

The Southshore priority area is shown on Figure 43. The field study and subsequent analysis determined that Southshore contains the following numbers of houses in each level of vulnerability. Note that these figures are current up to 30 June 2014 and reflect the best information available up to that date.

23.1 Flooding history

The predominant flooding issue in Southshore is caused by tidal influences on the stormwater system, made worse by a number of additional factors. These include:

- Earthquake damage to existing storm water infrastructure and carriageways disrupting flow paths to storm water outlets.
- Localised property damage (subsidence) giving rise to localised ponding.
- Flap gates requiring maintenance; some are stuck open, some sealed shut. The consequence of this is there is no effective outlet for street drainage and in some cases the tide is allowed back up through the stormwater system.
- Sumps requiring maintenance; localised nuisance flooding at intersections has been largely attributed to blocked sumps.

Customer Service Reports (CSRs) indicate historic flooding issues around the intersection of Owles Terrace and Beresford Street.

The Canterbury earthquake sequence has had significant effect on the stormwater network in the Southshore area and SCIRT are currently planning or undertaking construction of three stormwater pump stations and associated reticulation, as well as repairing or relaying a large proportion of existing reticulation.

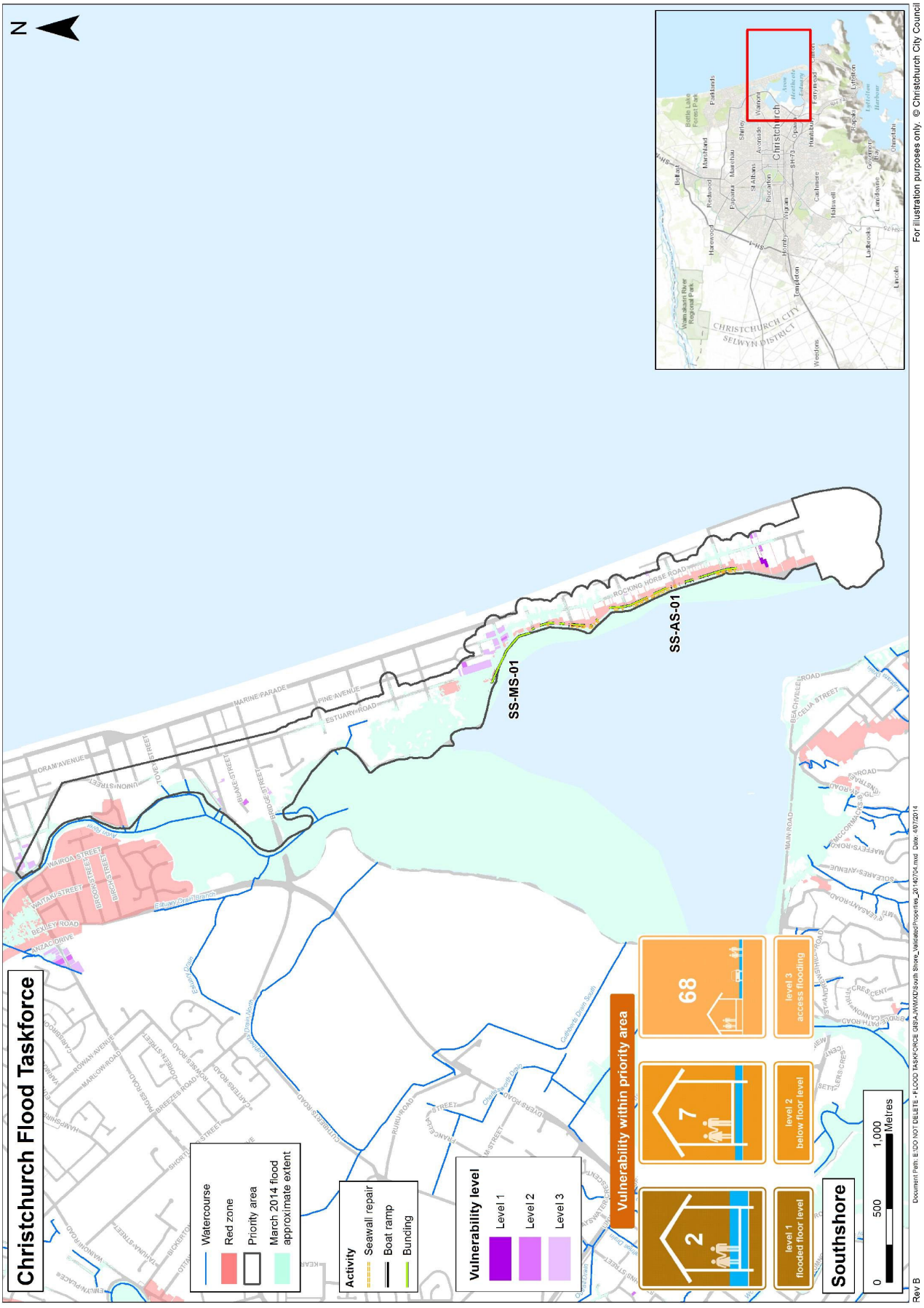


Figure 43 Southshore priority area and proposed works

Field studies

Field visits were undertaken May and June 2014 to better understand the flooding issues experienced. This included visiting problem areas identified after the March event, checking all the flap gates into the estuary and speaking to contractors working on existing SCIRT contracts on Kibblewhite Street.

Where encountered local residents were surveyed, including residents who had raised concerns and had localised property flooding.

A subsequent site visit with SCIRT contractors was undertaken to all vulnerable locations throughout the priority area and temporary work solutions and action plans in the event of another severe weather/ tide event were determined.

A walkover of the Southshore Red Zone was also undertaken with representatives from CERA to assess the increased vulnerability to tidal flooding being potentially created by clearance of Red Zone properties and damage to existing private seawalls.

23.2 Community engagement

23.2.1 Community meetings

A public meeting was held in Southshore on 5 June 2014 where an update on the Taskforce work was provided. A summary of questions and answers addressed at the meeting is on the Council website.

23.2.2 Resident surveys

In the Southshore area 39 households completed a questionnaire.

23.2.3 Other engagement

A site walkover was undertaken with a representative from each of the Southshore Residents Association and the Community Board. This specifically looked at concerns raised around the erosion damage to the Ebbtide Street stop bank and the increased vulnerability created by clearance of the Red Zone. Much of the flooding around these areas in the March event was related to seawater ingress around or through vulnerable sections of existing protective measures.

Discussions were also had with residents affected by flooding caused by localised settlement at a number of properties on Rocking Horse Road, and also those affected by tidal flooding in the Kibblewhite Street area.

ECan, MKT, the Harbour Master and Ihutai Trust were consulted regarding repairs required to Ebbtide Street stop bank.

23.2.4 Key issues identified by the community

There are wider community concerns in Southshore about sea level rise and the measures Council are considering to address this.

Other issues raised by residents at public meetings and through survey feedback included:

- Tidal flooding through damaged or poorly maintained flap gates, and whether there will be a review of how this maintenance is managed.
- Localised flooding on properties as a result of land settlement and loss of ability to drain to the road or other outfalls.
- Section 72 Hazard Notices for flooding being placed on titles as a result of the building consent process for earthquake rebuilds.

23.2.5 Social impact

Discussions with the community illustrated that there were concerns with the tide levels, but a general understanding that once the SCIRT works are completed these would largely be resolved.

23.2.6 Response required

Meetings were arranged for those affected by s.72 notices. This occurred on Thursday 26 June.

23.3 Short-term flood defence recommendations

This section contains a summary of the recommendations for the Southshore priority area. The full range of options considered, key assumptions, gaps and constraints, as well as costs are documented in the appendices.

23.3.1 Maintenance

- Ongoing maintenance of existing stormwater outfalls and flap gates is required by Maintenance Contractor until SCIRT projects are complete.
- Repairs to the Ebbtide Street stop bank are underway and will reinstate the original design level of protection that was provided by the stopbank.

23.3.2 House defence

A limited number of properties are experiencing regular on-property flooding as a result of localised land settlement. In some cases, the affected houses are to be rebuilt which will provide opportunity to address this. However, some will only be repaired and will require specific measures to mitigate on-property flooding. Where land and drainage cannot be modified to provide positive drainage to the road this is likely to require a local pumping solution. This is largely an EQC issue that will need to be resolved on a case by case basis with those affected.

23.3.3 Local area schemes

SS-AS-01 Southshore Area Scheme - Red Zone Tidal Protection
South Shore Red Zone Godwit St to Tern St

Description:	Work to provide a minimum level of protection from tidal flooding of the cleared Red Zone properties fronting the estuary has been identified. This includes ground shaping or importing of material to form an earth bund to achieve a continuous physical barrier along the estuary frontage, and also repairs or topping up of damaged or inadequate seawalls. Based on a site walkover, survey and review of past flood defence measures implemented at the adjacent road ends, it is recommended that the minimum height of the bund be 11.2m and seawalls 10.9m.
Confidence level:	High
Design stage:	Concept

23.4 Work completed to date

Repairs have commenced on the Ebbtide St stop bank to repair erosion damage and reinstate structural integrity. This will provide improved protection against tidal flooding in adjacent Estuary Road, Caspian Street and Rocking Horse Road.

SCIRT have completed the new stormwater reticulations serving Kibblewhite and Falcon Street and are currently working on Bridge Street. This will address the regular tidal flooding experienced in these areas due to damaged outfalls and flap gates. The area will remain vulnerable to large storm events until the new storage basin and pump station are completed in early 2015.

Field inspection and survey has been completed to scope the work required to address the increased flooding vulnerability caused by clearing of the red zone and damaged private seawalls.

23.5 Recommendations for investigation or future work (not costed)

Ebbtide Street stop bank

Maintenance work has commenced as emergency work under Section 330 of the RMA. A retrospective resource consent needs to be applied for.

South Shore Red Zone clearance

A significant number of properties have already been cleared and urgent work is required to mitigate the flooding risk. As the land is owned by CERA, agreement is required as to how this work will be delivered and how it will be funded.

Coastal defence system for Southshore

Ultimately, Southshore and South Brighton will require stop bank protection to be extended from Bridge Street through to the end of the spit. The Red Zone land provides a logical opportunity for this to be realised if it could be made available for this purpose.

SCIRT projects

Completion of the SCIRT projects in the Owles Terrace, Kibblewhite/Bridge Street, and Southshore areas will address the remaining flooding issues in the affected areas.

24 Sumner

The Sumner priority area has been divided into two areas, Sumner Village and Moncks Bay, as shown on Figure 44. The field study and subsequent analysis determined that Sumner contains the following numbers of houses in each level of vulnerability. Note that these figures are current up to 30 June 2014 and reflect the best information available up to that date.

24.1 Flooding history

Sumner Village

Mariner Street and Esplanade have a history of flooding and were affected significantly in the October 2000 flood event. Sections on Clark Street and Arnold Street also have a history of flooding as a result of the low lying typography of this area and proximity to the Sumner Main Drain (SMD). Sections on Paisley Street near the Sumner Stream/SMD also have a history of flooding.

As a result of the October 2000 Sumner Flooding stormwater drainage improvements were completed on the Richmond Hill Road waterway. These included the Nayland Street culvert and high level weir which reduces the loading on the pipeline through Richmond Hill walkway by diverting flows through to Burgess Street. During the March flood the Cave Rock outfall was operational and flooding in this area was not as significant as previous events. However, information from residents suggests the Burgess Street pipeline was surcharged which resulted in flooding in Mariner Street.

Tidal flood protection for the stormwater network in Sumner Village is limited to flap gates on approximately four of the ocean outfalls.

The main cause of flooding in the March 2014 event was the depth of the rainfall event coinciding with the very high tide with operation and maintenance deficiencies increasing the effects. In this event the Taskforce identified seven houses were flooded above floor level and 42 houses up to foundation level. These were located in areas which are either adjacent or in close proximity to the SMD.

One property has had floor level flooding twice and nine have suffered under floor level flooding more than once since 2010.

Moncks Bay

Cliff Street has a history of flooding due to area being the lower than surrounding streets. Main Road has a history of flooding as the Rifle Range Drain secondary flow path spills over the road, however only a few houses (127, 129 and 149-153) opposite Barnett Park and the Moa Community Kid Learning Centre reported flooding above floor level in the March flooding event.

Flap gates are present on approximately 70% of outfalls in Moncks Bay to help protect against tidal flooding.

During the March 2014 event land in the Moncks Bay area was inundated due to fluvial and tidal flooding. This has various contributing causes:

- Operation and maintenance

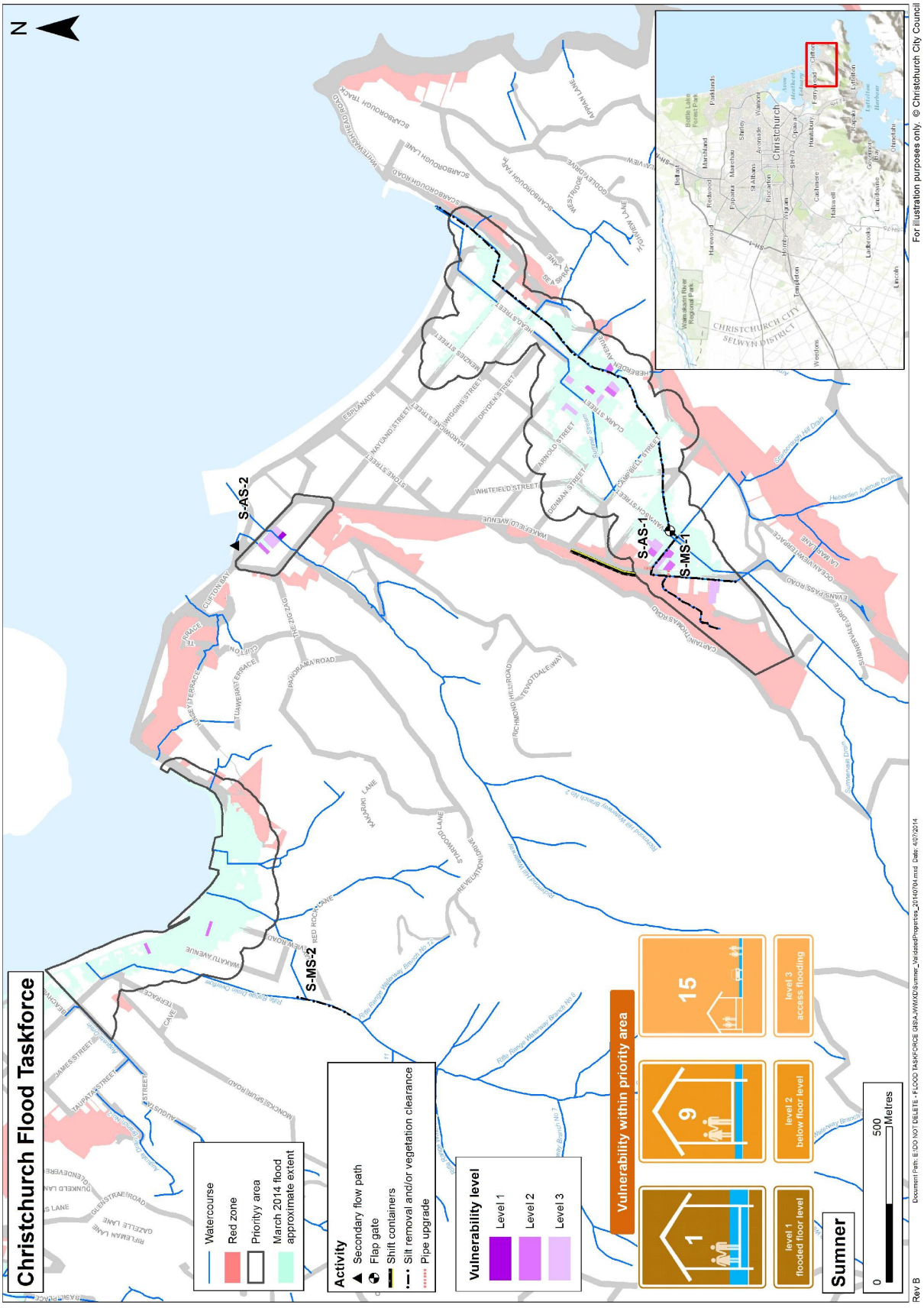


Figure 44 Sumner priority area and proposed works

- Secondary path overland flow and existing low lying topography
- Tidal flooding in conjunction with rainfall events

Approximately six houses were flooded above floor level and 61 houses suffered flooding up to the foundations during the March event in properties located in low lying areas in Bayview Road, Cliff Street, Wakatu Avenue and properties around the Rifle Range Drain.

One property on Main Road has reported flooding above floor level three times since 2010.

24.2 Field studies

A field visits were undertaken in May and June to better understand the flooding issues.

A number of known flooding and problem areas were visited and issues identified, including Cave Rock and SFRP outfalls, Sumner Stream, the SMD and the Rifle Range Drain.

24.3 Community engagement

24.3.1 Community meetings

Public meetings were held on 5 May and 29 May.

24.3.2 Resident surveys

Within the Sumner / Moncks Bay area 23 households completed a questionnaire.

24.3.3 Other engagement

Residents from the following locations were spoken during field investigations over the last two months: Main Road, Bay View Road, Mariner Street, Colenson Street, Arnold Street, Campbell Street, Paisley Street, Wakefield Ave and Finnsarby Place.

24.3.4 Key issues identified by the community

- Vulnerability of outlets to blockage (Cave Rock and Burgess St) and effective emergency response to blockage
- Secondary flow path from Cave Rock Drain to beach (near surf club)
- Surcharging from manholes on SFRP and apparent jamming of flap gate
- Sediment build-up and apparent loss of capacity of Sumner Stream
- Sediment and runoff from Red Zone on Wakefield Ave
- Effect containers on Wakefield have of diversion of runoff across Paisley St intersection

24.3.5 Social impact

Households with floor level flooding experienced considerable impact. The wider community was impacted by residential property flooding and restricted access to amenities including Sumner School, the retail sector and the main access into Sumner through Mariner Street.

24.3.6 Response required

- Action promised sediment cleaning from Sumner Stream and shift containers on Wakefield Ave
- Address other Task Force recommendations and communicate progress to community

24.3.7 Community feedback

During site inspections many residents noted that diligent operation and maintenance of the Cave Rock and Burgess Street outfalls is essential in flood prevention of Mariner Street and Nayland Street.

Many residents actively maintain local kerb and channels by clearing silt and debris to prevent localized flooding such as at Finnsarby Place.

A community meeting was held on 5 May 2014 where Sumner Village residents were able to confirm the extent of the March flood event and houses which were affected.

In the Moncks Bay area community feedback during site visits confirmed areas of flooding around Barnett Park and that the March event is the only time flooding has occurred above foundation level.

24.4 Short-term flood defence recommendations

This section contains a summary of the recommendations for Sumner and Moncks Bay. The full range of options considered, key assumptions, gaps and constraints, as well as costs are documented in the appendices.

24.4.1 Maintenance

- Removal of sediment from Sumner Stream between Sumnervale Drive and the outfall is scheduled to be undertaken in June.
- The shipping containers on Wakefield Ave are to be repositioned to allow drainage to and along the kerb and channel. A shallow drain will also be constructed behind the kerb to assist control of hillside runoff. This will improve control of runoff around the Wakefield Ave and Paisley Street intersection.
- Replace missing flap gate on DN225 pipe outlet to Sumner Stream on Van Asch Street (Asset SWOT-12496).
- Clear debris and silt from Finnsarby Drain to minimize overflow through red zone properties to green zone properties on Wakefield Ave.
- Secure lids on Sumner Flood Relief Pipe (SFRP) manholes to prevent surcharging.
- Service SFRP flap gate – remove debris restricting operations, ensure upper and lower hinges are operational, remove shellfish and silt build-up to allow gate to close properly.
- Clean out road side swale on Heberden Ave opposite Arnold Street to prevent overflow into 36a Heberden Ave.
- Clear silt from Rifle Range Drain Overflow weir and reform the channel upstream of Bay View Road end to increase the cross sectional area and prevent spilling down Bay View Road.
- Widening of the access point through the chain fence to allow vehicles/machines to enter into area to complete regular or emergency maintenance and cleaning of inlet structure.

24.4.2 House defence

No house defence measures are proposed in this area.

24.4.3 Local area schemes

S-AS-01 Sumner Area Scheme - Wakefield Ave / Paisley Street Drainage

Description:	Improve inlet capacity in Wakefield Ave and Paisley Street area by installing double sumps each side of Wakefield Ave at low point and one on north side of Paisley Street at intersection with Wakefield Ave
Confidence level:	High
Design stage:	Concept

S-AS-02 Sumner Area Scheme - Cave Rock Drain Secondary Flow Path

Description:	Design and construct permanent hard outfall from Cave Rock Drain to formalise secondary system protecting Mariner Street area
Confidence level:	High
Design Stage	Concept

24.5 Work completed to date

Survey work has been completed around the Wakefield Ave / Paisley Street area to enable design of the additional sumps and pipes.

Works orders have been issued for the following works:

- Removal of sediment from Sumner Stream along between Sumnervale Drive and the outfall. This is scheduled to be undertaken in June/July.
- The shipping containers on Wakefield Ave are to be repositioned to allow drainage to and along the kerb and channel. A shallow drain will also be constructed behind the kerb to assist control of hillside runoff. This will improve control of runoff around the Wakefield Ave and Paisley Street intersection. This is scheduled to be undertaken in June/July.

24.6 Recommendations for investigation or future work (not costed)

Operational expenditure:

- Develop and implement emergency response plan for Sumner to ensure that key outfalls are able to operate effectively prior to a forecasted storm event. This requires comprehensive documentation of key outfalls and inlets. Consider involving other local services such as the fire brigade in the response plan.

Capital expenditure:

- Establishment of a permanent secondary outfall to the beach from the Cave Rock Drain adjacent to the Surf Club.
- Install cut-off drain behind green zone properties on Wakefield Ave to control hillside runoff and secondary flow from the end of Finnsarby Place. This work should be considered with other silt control measures as part of the red zone clearance work being undertaken by CERA

Maintenance:

- Regular maintenance of SFRP flap gate to ensure that it is effectively operating.
- Sumner Stream – silt build up should be monitored four times a year, particularly in the upper sections until red zone demolition is complete and permanent silt control measures are operating effectively. Loss of capacity of the open and piped sections on Wakefield Ave and Paisley Street contribute to regular on property and underfloor flooding of several properties in this area.

25 Lyttelton

On 12 May 2014 the Christchurch Flooding Taskforce presented to Council options for the temporary protection of the city's most vulnerable residents from flooding. In response the Mayor requested a range of further investigations including asking the taskforce to "*Urgently review criteria for assessing flood risk and land movement in Lyttelton to improve the analysis of vulnerability and strategic infrastructure."*

This directive stems from the fact that flooding issues in Lyttelton have been identified as differing in nature from those experienced across much of Christchurch. Specifically, the steep nature of Lyttelton results in fast flowing and concentrated floods that can endanger human life and cause significant localised damage. Unconstrained floodwaters also have the potential to saturate steep slopes and increase the likelihood of landslips and retaining wall failures.

The vulnerability analysis conducted for the rest of Christchurch focussed on the flooding observed since the earthquakes. This method of assessment is appropriate across the flat parts of the city because the extent of flooding in these areas correlates relatively consistently with severity of the rainfall. Hence subsequent events can be expected to impact upon the same parts of the city. However in Lyttelton the unstable nature of the upstream catchment and geotechnical risks associated with saturated ground render this method inappropriate. Instead sediment and debris flow from the upper catchment, and saturation of the ground throughout Lyttelton, result in a cumulative risk effect where risk events can be triggered irregularly. In other words previous flood impacts do not provide sufficient insight into the likely consequences of future flood events.

For this reason a modified risk assessment approach has been developed for Lyttelton to determine priority categories for investigation and works. This approach is outlined in the following section, followed by a description of how the approach has been applied.

25.1.1 Earthquake effects

Whilst some drainage and geotechnical risks in Lyttelton pre-date the Canterbury earthquake sequence, the earthquakes have increased risks in a number of ways:

- *Land damage:* Settlement of road surfaces, including kerbs, channel and driveway cross-overs, has increased the incidence of stormwater spillage.
- *Infrastructure damage:* damage to stormwater infrastructure increases system leakage and causes saturated ground which can lead to geotechnical risk.
- *Increased debris load:* The earthquakes resulted in landslips and rock fall in the drainage catchment above Lyttelton, which increased debris load to the stormwater system and increased the incidence of inlet blockage.

25.2 Approach

A qualitative risk assessment approach was adopted, consistent with the Risk Management section of Council's Stormwater Asset Management Plan. This approach involves assigning consequence and probability scores to risk events in order to determine a priority level for investigations and mitigation works. In order to apply this method it was necessary to identify potential modes of failure and determine how these failures would impact residential properties and strategic infrastructure. The priority levels allow identification of critical assets and prioritisation of investigations and mitigation measures, but do not constitute a comprehensive risk assessment.

25.2.1 Study extent

The study covered all of Lyttelton from the intersection of Park Terrace and Cressy Terrace to the intersection of Reserve Terrace and Sumner Road. Residences and strategic infrastructure were considered, but commercial premises and non-strategic infrastructure was excluded. A total of 1,549 residences are located within the study area. Strategic infrastructure includes:

- Emergency services
- Pipelines
- Port
- Roads and rail servicing the port
- Roads connecting Lyttelton to the rest of Christchurch
- Schools
- Substations
- Tunnel entrance
- Wastewater treatment plant
- Water supply reservoirs

25.2.2 Failure modes

Representatives of Council's Land Drainage Team, in conjunction with geotechnical and drainage engineers, prepared a list of likely failure modes. Failure modes are actual or potential causes of flooding to residences or strategic assets. Typically the failure modes will be remote from the location of the impact and can impacts on more than one property.

25.2.3 Events

The same group of council representatives and engineers identified the events that might arise from the failures identified above. These events are the pathways by which the flooding impacts are directed from the origin at the failure point, to the location where the impact occurs.

25.2.4 Risk matrix

The risk matrix from Council's Stormwater Asset Management Plan required consequence and probability to be estimated for each impact, and this was used to determine priority.

25.3 Results

This section summarises the results of the priority assessment process.

25.3.1 Residential risk

Two hundred and twenty-seven (227) residences in Lyttelton were determined to be high or medium priority to protect from flood-related events. Several properties are at risk from more than one failure mode / event combination. In this case properties have been assigned an overall priority according to the highest priority score. For this reason the total number of properties at risk in Table 12 does not necessarily match the more concise summary of Table 11. The following tables provide a summary of flood investigation and mitigation priority of residences in Lyttelton:

Table 11 - Number of residences at risk by score

Priority score	Number of residences
High	89
Medium	138
Low or nil	1,322

Table 12 - Number of residences by failure mode and priority score

Failure Mode	High	Medium	Total
Saturated Ground	27	55	**82**
Private Drainage [1]	12	9	**21**
Blocked Inlet	40	49	**89**
Tunnel Erosion [2]	2	1	**3**
Road Spillage	15	50	**65**
Water Main Leak	3		**3**
Pipe Blockage		1	**1**
Grand Total	**99**	**165**	**264**

[1] This indicates risk associated with private drainage faults on 14 individual properties. This takes into account only private drainage faults that could be readily identified during this risk assessment procedure. The number of properties at risk from private drainage faults is likely to increase if further investigations are completed. Refer to the *Private Drainage Investigation Pilot* section below for more information. Results from the Private Drainage Investigation Pilot have not been included in these summary tables.

[2] This indicates tunnel erosion risk on two individual properties.

25.3.2 Geotechnical Hazard Areas

The geotechnical risk assessment process that informed the overall risk assessment identified 20 geotechnical hazard areas. These areas were deemed to be especially susceptible to slope failures resulting from drainage network faults. There are 273 Lyttelton residences within the identified geotechnical hazard areas.

25.3.3 Risk to strategic assets

The following table summarises the priority relating to strategic infrastructure.

Table 13 Risk to strategic assets

Strategic infrastructure	Priority score	Risk description
Waste Water Treatment Plant	High	Various road spillage, inlet capacity and lack of network issues uphill of the WWTP present a high risk.
Somes Road Water Supply Reservoir	High	Blocked inlet on Canterbury Street
Brittan Terrace	High	Blocked inlets on Cressy Terrace and/or Brittan Terrace
Simeon Quay Substation	High	Blocked inlet on Bridle Path,
Brittan Terrace Substation	High	Blocked inlets on Voelas Road and/or Harmans Road
Lyttelton Port Company	Medium	Blockage of Canterbury Street brick barrel

Gladstone Quay Storage Tanks	Medium	Blocked inlets on Randolph Terrace and Reserve Terrace

25.4 Private drainage investigation pilot

Whilst applying the approach described above, it was observed that inadequate and faulty private drainage infrastructure contribute to the risk of flooding and geotechnical failure and that the above approach does not provide sufficient resolution to quantify and prioritise these risks. Hence a pilot study was conducted with the aim of:

a) Trialling an approach to investigation of private drainage infrastructure faults and impacts;
b) Demonstrating the impact of private drainage faults on flood and geotechnical risk; and
c) Scoping preliminary remediation options.

25.4.1 Study location

The study focussed on approximately 40 houses near the intersection of Bridle Path and Ticehurst Road. This location was selected on the basis that private drainage issues in this area have the potential to exacerbate geotechnical instability and the consequence of geotechnical failure is high, potentially including severe damage to houses and blockage of the road tunnel entrance.

25.4.2 Pilot study results

Visual inspections were completed at 39 properties in the study area. A description of the private drainage arrangement was collected for each property, including photographs. In order to summarise the findings of the investigation the properties we assigned to one of three categories as follows.

Category	Description	Count
No faults	The property appeared to have private drainage infrastructure adequate to drain roof and hardstand areas to the Council stormwater network without adverse impacts on their own section or neighbouring sections.	13
Minor faults	The property had private drainage faults that had the potential to damage that property but were unlikely to cause adverse impacts to neighbouring properties. Likely cross-connections to sewer were also assigned to this category.	15
Major faults	The property had faults that were significant enough to potentially cause damage to both their own property and neighbouring properties.	11

When the risk associated with these faults was assessed it was determined that four properties were high priority and six moderate priority. If these results were extrapolated across all geotechnical hazard areas, it could be expected that there are approximately26 additional properties with high priority and 40 additional properties with medium priority. Based on this extrapolation, it seems likely that if private drainage faults are considered as a group then they present the largest stormwater related risk in Lyttelton.

25.5 Risk mitigation options

This section presents options to mitigate risks to residences and strategic assets in the high priority category.

25.5.1 Blocked inlets – initial inlet

Many of the inlets identified as causing flood risk were the initial inlets where the open drainage network goes underground. These inlets can quickly block with debris during storm events. To reduce the risk of blockage debris screens and inlet enlargement could be considered.

Debris screens would typically consist of one to two dozen piled posts, approximately 5m long with 1-2m exposed above ground. The screen would be located short distance upstream of the inlet, in a position that allows machinery access for cleaning. Depending on the size of the screen required, the underlying ground conditions and the ease of access for construction, the cost is likely to range $25,000 to $50,000.

Inlet opening size has also been indentified as an issue in some cases. As a guideline the inlet opening should be 10-20 times the pipe area, whereas some inlets are as small as 1.5 times. Depending on site considerations the estimated cost to increase the inlet size will be $50,000 to $100,000.

Risk associated with failure of these inlets could be reduced by increasing the frequency with which these critical assets are maintained, and by focussing on ensuring these assets are operational prior to predicted rainfall events. Improved maintenance of gravel roads upstream of at risk inlets would also reduce the risk of failure.

25.5.2 Blocked Inlets – catch-pits

Some catch-pits are susceptible to blockage. Where these pits are in critical locations they have been identified as risks. The likelihood of these catch-pits blocking can be reduced by increasing their inlet capacity, typically by converting them to double or quadruple sumps. The comments relating to maintenance of initial inlets also apply to maintenance of catch-pits.

25.5.3 Road spillage

Road spillage as a result of damaged or inadequate road drainage infrastructure can be reduced by minor re-grading works of the road and/or footpath and installation of kerb and channel.

25.5.4 Saturated ground

The limited nature of the geotechnical investigation associated with this risk assessment means that further work needs to be completed to understand the causes and potential remedial options associated with the identified areas of saturated ground.

25.5.5 Private drainage

The Private Drainage Pilot Investigation showed that there is significant risk associated with private drainage faults in Lyttelton. As a step toward properly quantifying the magnitude of this risk and identifying necessary remedial works, the investigation could be expanded to cover all properties within the identified geotechnical hazard areas.

Once all properties were assessed Council could instigate a program to encourage (or compel) residents to rectify private drainage issues on their property. Where a high risk is posed to neighbouring property, house owners should be encouraged to rectify private drainage issues as soon as practically possible. Uninhabited properties and those scheduled for demolition may pose additional challenges as these properties may not be safe to work on, or have practical means available to resolve the faults.

25.6 Costs

Costs have not yet been calculated for mitigation works as further investigation, prioritisation and concept design is required first.

26 Little River

The Little River priority area is shown on Figure 45. The field study and subsequent analysis determined that Little River contains the following numbers of houses in each level of vulnerability. Note that these figures are current up to 30 June 2014 and reflect the best information available up to that date.

26.1 Flooding history

The Little River priority area is shown on Figure 45. This area has a long history of flooding problems. Generally flooding in the Little River area is due to flowing rather than ponding water. The area consists of a steep upper catchment that funnels into a flatter lower valley where the township is situated. From here water drains via the Okana River system through Te Roto Wairewa / Lake Forsyth to the sea. The outlet of the lake is artificially opened to manage the lake level.

During the field studies no evidence was found showing any difference between flooding pre- and post-earthquakes. There was little visible land damage and no evidence of land rising or falling in the catchment. Therefore, flooding is this area is not attributable to the earthquake series.

Land stability issues in the upper catchment that have caused slips and waterway blockages may be earthquake related but these could also be attributable to the recent high intensity rainfalls. In summary the recent spate of flooding seems to be related to the high rainfall intensity during recent events rather than changes in the catchment.

There have been three floods resulting in on-property flooding in 2014 (4 March, 18 April, 30 April) and a total of seven on-property flood events since the earthquakes.

26.2 Field studies

A field visit was undertaken in May 2014 to better understand the flooding issues experienced. During the field studies known problem areas along the rivers and streams from upper Cooptown down to the lake outlet were visited.

Prior to and during our visit enquires were made with members of the community, business owners, members of the Community Board, and Council staff to identify known and suspected flood prone houses. These were all visited and surveyed.

The photo in Figure 46 was taken from Okana River Branch 3 and indicates the level of vegetation in the watercourse.

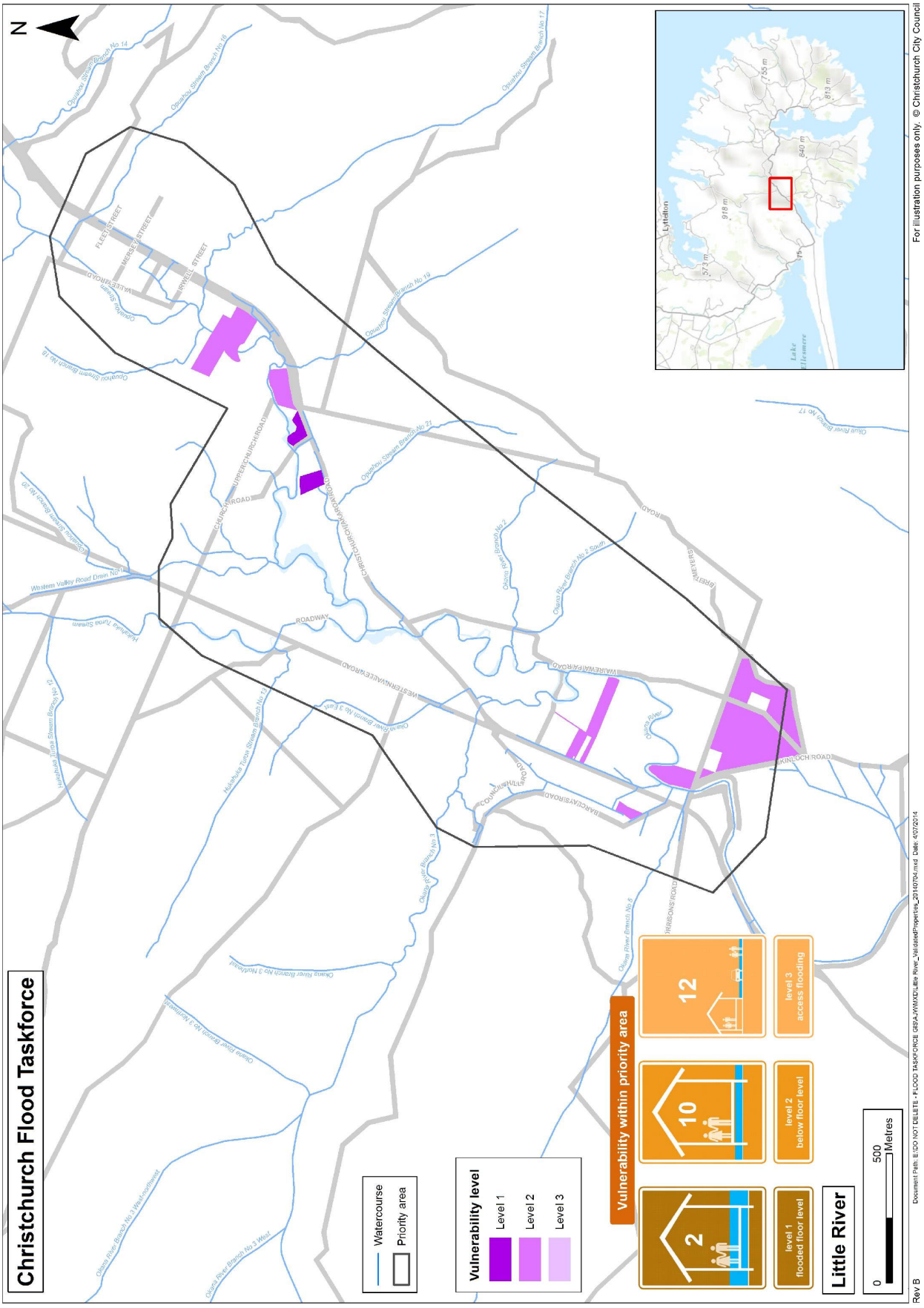


Figure 45 Little River priority area

Figure 46 Vegetation on Okana River Branch 3 (May 2014)

26.3 Community engagement

26.3.1 Community feedback

There have been very few complaints logged with the Council regarding residential flooding. In order to address the uncertainty, the investigations have involved discussions with domestic and commercial property owners in the area to identify vulnerable homes.

Key community members were contacted and their local knowledge used to identify which buildings to visit and also to recommend other people to contact. While in the field conversations with the residents also helped to gather more information and identify further sites to investigate.

26.3.2 Community meetings

A community meeting to discuss the causes of flooding in the area was held on the evening of Wednesday 21 May 2014 at the Little River Community Centre.

26.3.3 Resident surveys

Across the Little River area three households and two businesses have completed a flooding questionnaire.

26.3.4 Key issues identified by the community

The community identified the main cause of the flooding was the lack of maintenance of the waterways, including clearing of vegetation such as willow trees. The Wairewa Pa Road Bridge also restricts flow.

26.3.5 Social impact

While flooding in the Little River area only enters a few houses above floor level (six identified) it does have a significant impact on the community. A large number of properties have been inundated multiple times including close to floor level under houses and also entering into garages and ancillary buildings.

A number of commercial buildings have been flooded impacting on the owners and the associated businesses.

Road closures on the Christchurch Akaroa Highway impact the community by isolating the rest of the peninsula, preventing travel and limiting tourist activity. This affects both individuals and businesses.

Deep flowing water on the main road, often at night, creates a hazard to the local community and travelers.

26.3.6 Response required

The primary responsibility for maintaining waterways in this area is Environment Canterbury's (ECan) and private landowners. As such the matter has been referred to the joint Council and ECan Stormwater Issues Management Group (SWiM) for further investigation. The Taskforce has therefore discontinued further inquiries or recommendations into this area.

27 Other city areas

Survey data, analysis and field studies determined that outside of the priority areas there are the following numbers of houses in each level of vulnerability. Note that these figures are current up to 30 June 2014 and reflect the best information available up to that date.

27.1 Summary

Approximately 30 individual properties were inspected as part of field investigations undertaken on 19, 20 and 23 June 2014. Details of individual assessments are available to Council staff but this section summarises the findings.

The properties visited had experienced flooding affecting access to the property or resulted in flooding to the rear of the property. These flooding issues could be attributed to localised land deformation, increased overland flow from neighbouring properties or poor drainage maintenance.

Two areas in the Upper Heathcote catchment were identified which contained properties confirmed in the Level 1 and Level 2 vulnerability categories, and these are described in further detail below. One area in the Upper Heathcote was identified with flooding issues which affected the access (Level 3) to multiple properties.

All other properties visited were either Level 3 or not vulnerable and the issues only affect one isolated property. Flooding on these properties could be attributed to localised land deformation, increased overland flow from neighbouring properties, private drainage issues or maintenance issues to be addressed.

27.2 Greenpark, Upper Heathcote

Approximately 20 properties on Greenpark Street have experienced flooding which affects access to their properties more than 4 times since the earthquakes. A field visit was undertaken 20 June 2014 to investigate further the flooding issues experienced by residents. A resident from the area confirmed that the April storm event resulted in the most severe flooding to the street, however, due to the relatively high floor levels of the houses there were no situations where residents experienced below or above floor level flooding. During this event cars which were parked on the street were also flooded and stormwater was observed to be surcharging from manholes.

Greenpark Street backs onto the Heathcote River and further investigations are required to confirm if the stormwater outlet from Greenpark to Heathcote River includes backflow prevention. A single sump on Greenpark may also require upgrading to a double sump in order to increase the drainage capacity of the area.

27.3 Therese Street, Upper Heathcote

Approximately 15 properties on Therese Street have experienced flooding which affected access to their properties more than twice since the earthquakes. One property with a relatively low finished

floor level in comparison to both the road and surrounding properties has been classified as Vulnerability Level 2.

A field visit was undertaken 20 June 2014 to investigate further the flooding issues experienced by residents. During this field visit, a resident confirmed that the sump and deep dish channels regularly block with debris from the surrounding street trees and are actively maintained by residents on the street. The resident also confirmed that the upstream flow from the deep dish channel does not continue through the piped crossing at the intersection of Stourbridge Street and Therese Street but continues through an overland path onto the road and contributes significantly to the flooding issues on Therese Street (Figure 47).

Further investigations are required to confirm if damage has occurred to the stormwater crossing which could prevent upstream flow passing through to the downstream dish channel. Investigations are also required to determine if additional sumps are required on Therese Street which could potentially discharge to the Wilderness Drain.

Figure 47: Intersection of Therese and Stourbridge Streets

27.4 Marion Street / Copenhagen Street/Dalkeith Street, Upper Heathcote

Approximately 38 properties on Marion Street and Copenhagen Street have experienced flooding which affects access to their properties at least four times since the earthquakes.

A field visit was undertaken 20 June 2014 to investigate further the flooding issues experienced by residents. Residents in Marion Street reported that that stormwater has been observed as surcharging from vented manholes during flooding events and are concerned about the health risks associated with the contaminated water. It was noted during the field visit that manhole vents now are covered with plastic.

One property in Dalkeith Street has experienced under floor flooding twice this year and has been classified as Vulnerability Level 2 (Figure 48). The resident has noted that flooding in this area has increased since the earthquakes and that stormwater has difficulty draining through the single sump in located near the property which connects to the Ballintines Drain through DN450 stormwater pipes.

Further investigations are required to confirm if additional sumps are required on the corner of Kevin Street and Dalkeith Street in order to mitigate flooding in this area.

Both Marion Street and Copenhagen Streets are also part of the Ballantine's Drain catchment and Rain on Grid Modelling suggests that this area experienced some previous flooding issues prior to the earthquakes. The area has a high ground water table and a number of springs are located throughout the catchment. Flooding intensity may have increased post-earthquake due to land subsidence and loss of gradient or capacity in Ballintines Drain.

Figure 48: Dalkeith Street house after under floor flooding

27.5 McBratney's Drain

Site visits during validation in the McBratneys Road and Dallington area highlighted additional flooding issues. Current ground levels show that this area is potentially lower than the high tide level and could be susceptible to street and land flooding. Elevation change maps show that the area has suffered between 0.25 to 0.75 m of settlement as a result of the earthquakes.

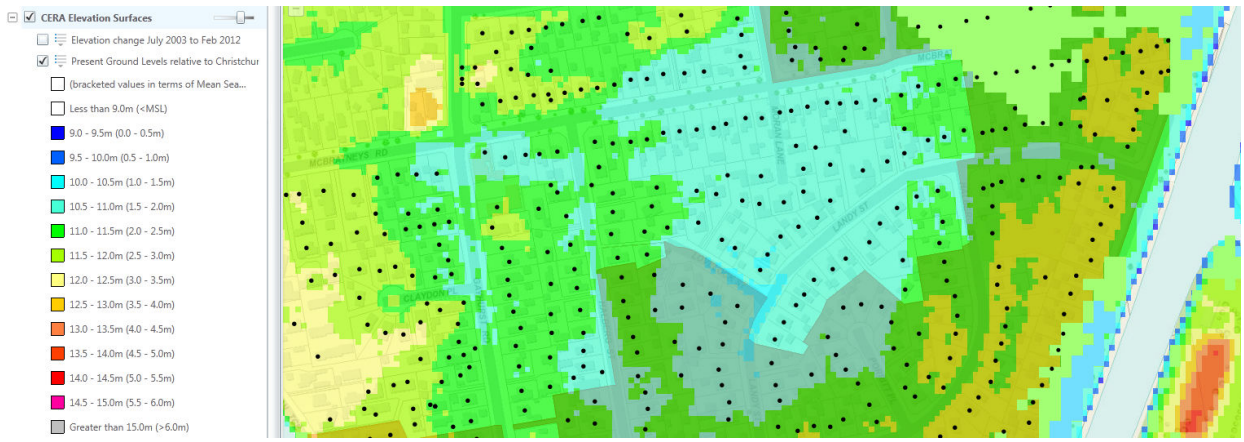


Figure 49 Current Ground Levels in Dallington (Source: http://maps.cera.govt.nz/)

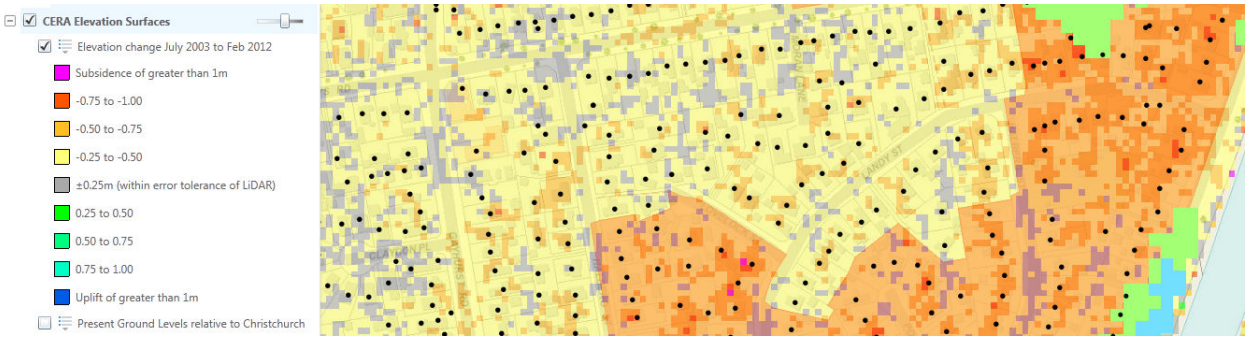


Figure 50 Elevation change post EQ in Dallington (Source: http://maps.cera.govt.nz/)

The stormwater network suffered damage during the earthquakes and is currently being assessed by SCIRT. Due to the low lying nature of the area backflow prevention may be required on the stormwater networks close to the Avon River.

Residents in the Avondale area highlighted that there was frequent street flooding in the larger storm events. Current ground levels in the Avondale area show that there are locations where the ground level is lower than the high tide level. This indicates that the area is susceptible to tidal and river flooding, investigations show that the main stormwater outlets in the area include a 600 mm diameter outlet on Breezes Road which does not have an outlet, 1350 diameter outlet on Hulverstone Drive which has a flapgate which is not functioning properly and a 600 diameter outlet on Avondale Road at the bridge which is to be installed by SCIRT.

The 600 mm diameter Breezes Road outlet has been investigated by SCIRT and the stormwater piped network has been disconnected from the surrounding piped network. The SCIRT project had not looked at the effect of overland flow to the green zone from the Residential Red Zone as a result of tidal backflow.

The 1350 mm diameter outlet on Hulverstone Drive is being reviewed by Council and SCIRT. The existing flapgate on the outlet does not seal correctly and is resulting in river and tidal backflows into the stormwater pump station and network. River and tidal backflow reduces the operational efficiency of the pump station and may contribute to street flooding and wastewater issues.

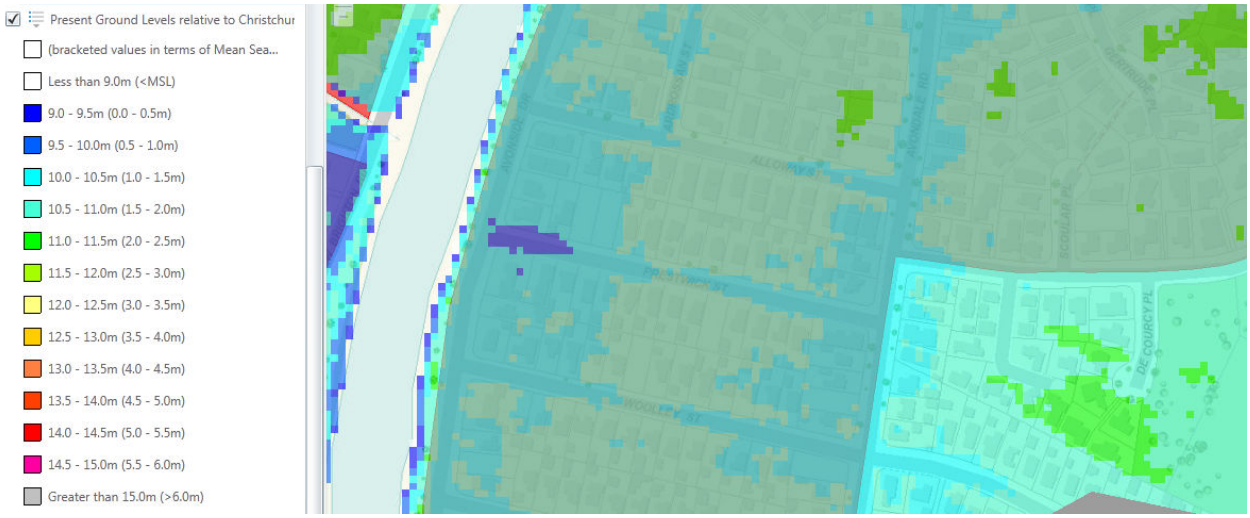


Figure 51 Current Ground Levels in Avondale (Source http://maps.cera.govt.nz/)

SCIRT are installing a flapgate on the 600 mm diameter stormwater outlet on Avondale Road as part of the roading rebuild.

Knights Drain residents highlighted regular flooding from the road onto the property and noted that there was regular ponding of water on the roads. SCIRT are currently undertaking design and

construction to the roading and stormwater network in the area. Residents noted that the majority of the flooding came from the roading network which is now higher that the properties.

Residents around Pamela Street Drain highlighted some property flooding causing land ponding, road ponding and access issues in Cheslea Street and Jollies Road. This may relate to the Pamela Street Drain and local historical poor drainage which may have been made worse by earthquake settlement. Chelsea Street residents noted that the majority of flooding came from the roading network. This ultimately is likely to a private property drainage issue.

27.6 Steamwharf Drain

Residents adjacent to the Steamwharf Drain in Alport Place met with Taskforce representatives on site. Residents commented that Steamwharf Drain was tidal and combined with rainfall caused regular flooding on and below properties. Residents noted that houses were becoming damp and required regular ventilation to prevent health issues.

27.7 Taylor's Creek

Taylors Creek is an area that flooded during the March 5 2014 event. It contains one Level 2 property, with potentially more that have not been verified. The recommendation for this area is to clear out the drain and ensure that the waterway has sufficient capacity to convey regular flood flows.