8. POST-EARTHQUAKE SEQUENCE FLOODING IMPACTS ON THE BUILT-ENVIRONMENT

In early 2014 Christchurch had the heaviest sequence of rainfall since the 1970s. Several large rainstorms fell in the city, saturating the ground, raising river and stream levels, and flooding homes, properties and streets. In many locations flooding was made worse by the effects of the 2011 Canterbury earthquake sequence (CCC Task Force 2014a), which had caused land to slump by up to half a metre in some areas, reducing capacity in many waterways, and damaging the pipe and outfall infrastructure (see Chapters 3 and 5 of this report for further details).

At a request from Christchurch Mayor Lianne Dalziel, the Christchurch City Council (CCC) set up the Mayoral Flood Taskforce (hereinafter “the Taskforce”) on 29 April, 2014 with the aim of finding immediate/short-term solutions for those residents severely impacted by the flood waters. The Taskforce started work on 1 May, 2014 with members from Council staff, engineering consultants, the Stronger Christchurch Infrastructure Rebuild Team (SCIRT), Environment Canterbury (ECan), the Canterbury Earthquake Recovery Authority (CERA) and the Earthquake Commission (EQC). The Taskforce was asked to report to the Council on 12 May, 2014 with a range of temporary solutions that would help reduce or defend against flooding in the near future. Taskforce field engineering teams carried out an area-by-area analysis of the causes and scope of flooding problems in the following priority areas located in Figure 8-1a: Lower Avon River; Dudley Creek (Flockton); Lower Heathcote (including Woolston/Opawa); Upper Heathcote; Heathcote Valley Southshore; Sumner (including Redcliffs); Little River; and Lyttelton. The Taskforce field teams: a) identified the flooding issues; b) quantified the effects of earthquake damage; c) assessed frequency of inundation above or below floor level; d) and designed appropriate house defence or local area scheme. Details of the findings from the Taskforce work are presented in the CCC Task Force (2014a) report and related Appendixes (CCC Task Force 2014b; CCC Task Force 2014c).

This section focuses on the 5th March, 2014 flood impacts and on the concomitant and combined earthquake-induced contributing impacts. Attention is given therefore to the Taskforce findings related to: flooding issues[1]; effects of earthquake damage; and frequency of inundation above or below floor level. The presentation and discussion of the temporary flood defence measures, i.e. immediate/short-term solutions suggested by the Taskforce to the residents is beyond of the scope of this report (technical details can

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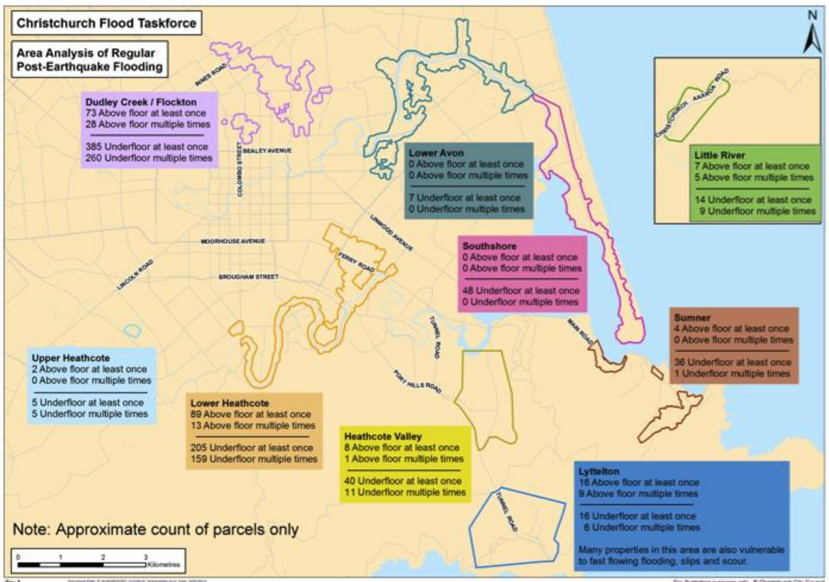
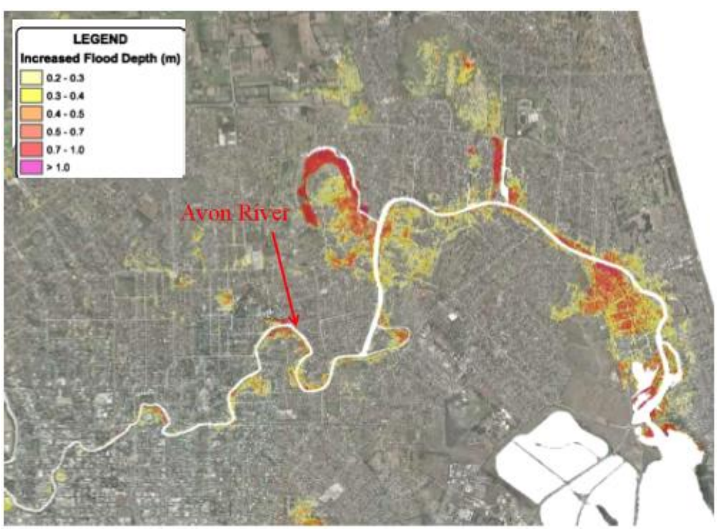
[1] Note from Taskforce report (2014a): *The Taskforce field teams had only five days to carry out all of the above work, so engineering judgement and interpolation was necessary. However the Taskforce considers the process was sufficiently robust to give a high level of confidence in the key findings.*

be found at CCC Task Force 2014b). The focus is on areas where earthquake-induced geotechnical and tectonic impacts on flooding where discussed by the GEER team in Chapter 5, namely in the areas of: 1) Lower Avon River (Figure 8-1b and dark green boundary in Figure 8-1a); 2) Dudley Creek, Flockton area (Figure 8-1b and purple boundary in Figure 8-1a); 3) Lower Heathcote (Figure 8-1c and dark yellow boundary in Figure 8-1a). These areas suffered the most severe flooding after the 5th March event as shown in Figure 8-2.



(a)



(b)

(c) 

Figure 8-1Areas of investigation by the 2014 Mayoral Flood Taskforce (CCC Task Force, 2014a): (a) Summary map of Christchurch outlining investigation areas; (b) Avon River area of investigation; (c) Heathcote River area of investigation.

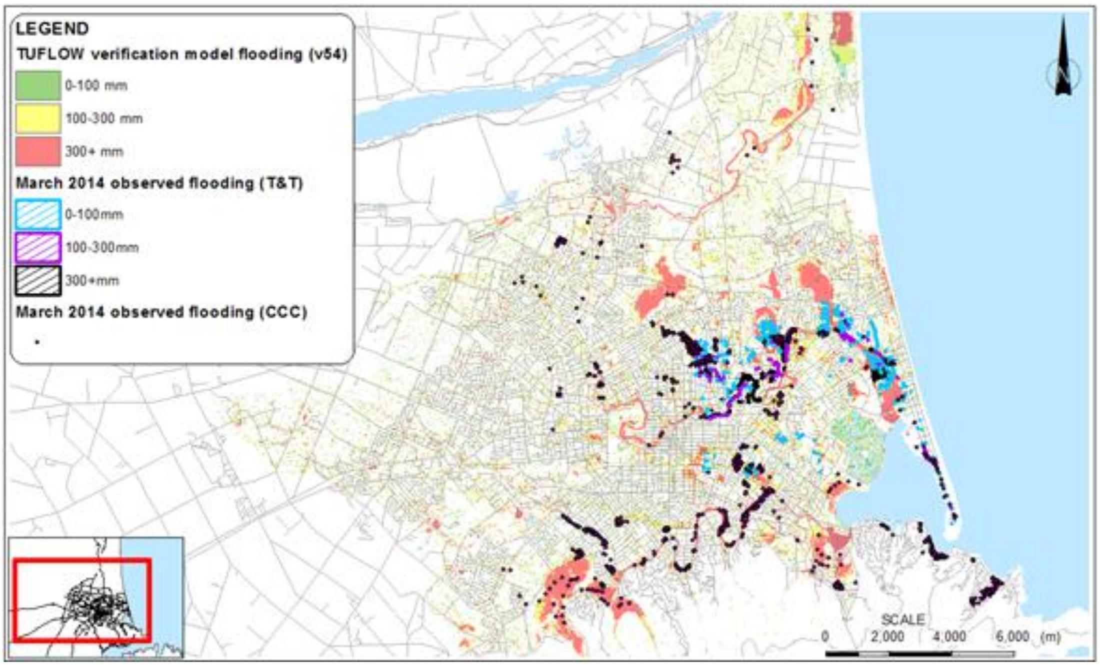


Figure 8-2 Observed Flooding in Christchurch March 2014 with hind cast model predictions (courtesy of Tonkin & Taylor, 2014).

Lower Avon River

Flooding history, existing flood protection and key drainage infrastructures

Stopbanks were first constructed along some lengths of the Avon River in the early 20th Century. During major storm events the river has over topped its banks leading to progressively higher and longer lengths of stopbanks. Stopbank over topping during the 1992 snow-storm resulted in a major extension of the stopbank system (see more details in Chapter 2). The area shown in Figure 8-3 is protected by the Avon River stopbanks and back flow protection devices on the stormwater network outfalls. There are numerous drainage pipes and open drain outfalls to the river, including discharges from three pump stations (CCC Task Force, 2014b).

Earthquake-induced tectonic-geotechnical effects and impacts on drainage and key infrastructures

Figure 8-3 shows the Lower Avon River area that was declared Residential Red Zone (RRZ)2 area after the 2010-2011 earthquake sequence. This area suffered significant ground settlement as a result of the earthquakes and is now typically at river level (RL)10.0 – RL11m. Vertical and horizontal ground movements in the range of -0.1 m to -0.5 m have been observed along the Avon, with some localised movement of -0.5 m to -1.0 m. As described in Chapter 3, moderate to significant liquefaction accompanied by moderate to severe lateral spread occurred along the length of the Lower Avon River and within the RRZ. The riverbed experienced heaving. Some parts of the RRZ area are now below annual high tide level and the river flood level for moderate to major storm events (CCC Task Force, 2014b).

The Avon River banks suffered significant slumping as part of liquefaction and lateral spreading. 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 portions of the stopbanks being lower than the river flood level.

Also the hydraulic head necessary for the local stormwater network to function as originally designed has been reduced, thus reducing the stormwater network’s efficiency.

The local drainage network suffers from a reduction in capacity during peak river levels due to ground settlement. Additionally, the emergency response placement of the stopbanks inadvertently covered some storm drain manholes and sumps causing local drainage issues.

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[2] Land designated after the February 2011 Christchurch earthquake for government purchase and clearing (http://cera.govt.nz/residential-red-zone). See Chapter 9 of this report for further information

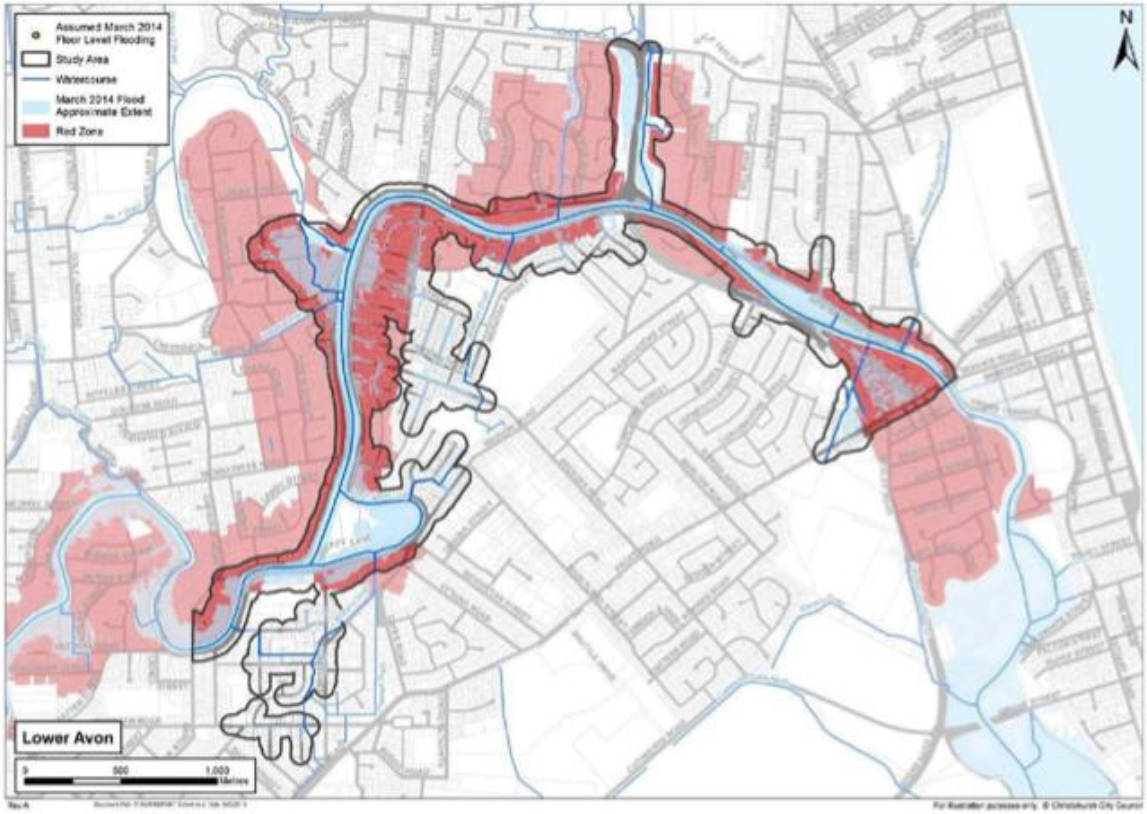

Figure 8-3 Lower Avon River: boundary of the area analysed by the CCC Taskforce and extent of March 2014 flood (map from CCC Task Force 2014b).

March 2014 flood extent

Flooding along the urban side of the stopbanks was caused by both: (1) the river floodwaters back flowing through the flap valves and (2) rainfall within the catchment (i.e., behind the stopbanks) not being able to drain into the river.

The river also over-topped the stopbanks in some locations. Bank overtopping occurred as a result of stopbank slumping and settlement and the flooding in these areas was exacerbated by post-earthquake maintenance practices of blocking off some piped stormwater outfalls. The blocking of outfall been undertaken primarily because: (a) post-earthquake stopbank restorations required some manholes to be covered and as a result prevents access to flap gates for maintenance; or (b) to prevent backflow from the river, but this resulted in surface ponding.

March 2014 flood impacts on the built-environment

The CCC Task Force did not investigate property level flooding for this specific area since the area is classified as RRZ. However, using GIS to overlay property map with the flood extent along the Avon River indicates about 396 properties experienced some flooding. Most of these properties would have been abandoned and likely demolished because they are in the RRZ, however not all homes have been abandoned. 120 houses in the RRZ were reported as flooded by the owners/residents, and 8 garages were confirmed as flooded outside the RRZ area. A number of properties also reported flooding up to the house foundations.

Dudley Creek (Flockton Area)

Flooding history, existing flood protection and key drainage infrastructures

The Dudley Creek catchment shown in Figure 8-4 has a history of flooding. Floods have been documented across the area dating back to the early 1900's. The area was then occasionally flooded up to the 1970's, until the Dudley Creek Diversion was constructed (Chapter 2) to divert floodwaters from the upper catchment to Horseshoe Lake, which had effectively controlled flooding up to present. Residents, who have lived in the area for 30 years, reported there was no flooding to the area before the 2010-2011 earthquake sequence. After the earthquakes, there have been several floods in the area, namely August 2013, June 2013, March 2014, April 18th and 30th 2014 (CCC Task Force, 2014b).

Dudley Creek and its tributaries are demonstrably under capacity in rainfall events both within the open channels and at culverts. One of the most vulnerable areas with the Dudley creek catchment is around Flockton Street, which has the general low-lying topography of a basin and during flood events often suffers from significant ponding. Underground infrastructure helps to drain this ponding; however, many of the water levels within the structure rely on hydraulic pressure. The Flockton Invert, located on Harrison Street, is a submerged pipe and water levels equalize with the Dudley Creek, which then results in a water level in the Flockton area being higher than the ground level because the Dudley Creek bank height is at the outlet invert (CCC Task Force, 2014b). There are no stopbanks or flood defences in the Dudley Creek catchment.

Earthquake-induced tectonic-geotechnical effects and impacts on drainage and key infrastructures

A large proportion of the catchment has subsided between 200 and 500 mm (Chapter 3 and Chapter 5). Bed heave has occurred extensively along Dudley Creek and its tributaries and a subsequent loss in hydraulic capacity has occurred (Chapter 3). Damage to culverts and failure of timber retaining structures has occurred across the lower catchment. Culvert repairs and replacements are proposed by SCIRT, and CCC has been undertaking remedial works, such as silt clearance, since the earthquakes. Further damage to the drainage infrastructures is being addressed through the SCIRT programme as described in Chapter 7.

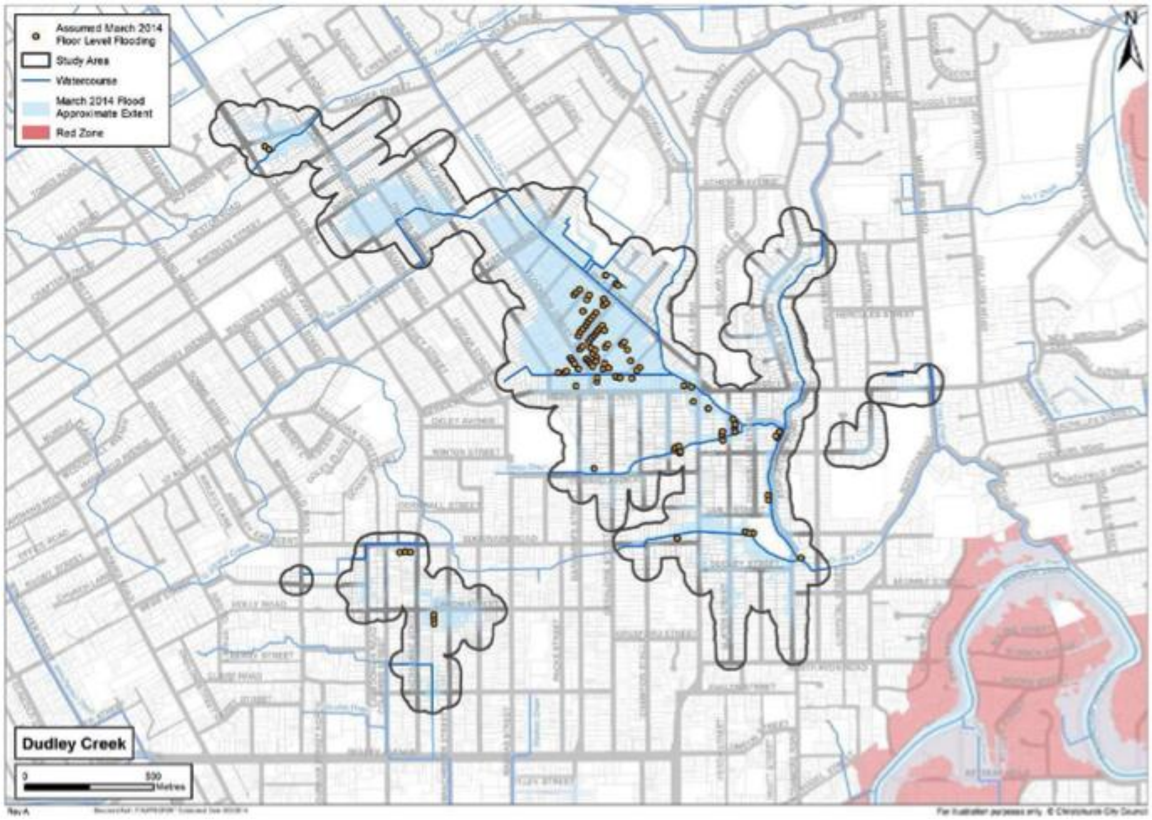

Figure 8-4 Dudley Creek location plan: boundary of the area analysed by the Taskforce; extent of March 2014 flood and location of flooded houses (map from Task Force, 2014b).

March 2014 flood extent

Figure 8-4 shows the extent of recorded pluvial floodwaters recorded from the March event, which exceeded 600mm in depth in some areas. Flooding in the Dudley Creek catchment resulted from the previously described under capacity waterways, which restrict flows causing water to back up in heavy rainfall. Additionally, flooding is enhanced from the significant seismic-induced ground settlement coupled with the waterways suffering from lateral spreading and bed heave. The inability of the waterways to convey flow has a direct impact on the ability of drainage infrastructure to function. Fluvial water backflows the associated piping and spills into the Flockton area exacerbating pluvial flooding issues.

March 2014 flood impacts on the built-environment

The Flockton area flooding caused an estimated 97 properties to experience water intrusion above floor level at locations shown in Figure 8-4. This number of flooded properties was based on GIS data and the surveyed flood extent. For the wider area, the majority of properties experienced flooding across the section or under foundations.

Vehicles were also flooded and suffered damage. Local evacuations were required due to the risk of residential flooding.

Lower Heathcote

Flooding history, existing flood protection and key drainage infrastructures

The Heathcote River Flood Plain Management Strategy (1998) highlights the historic flooding of 73 houses before 1998 at least on four different occasions (i.e., 1968, 1975, 1977, and 1980). Works previously undertaken to mitigate flooding risk included: widening and deepening of the river channel and dragline operations on several occasions since 1920s; construction of the Woolston Cut (1986) to provide a more efficient flow of water; installing Woolston Tidal Barrage (1994); construction of the Wigram East Retention Basin; raising of 19 homes from 1983 to 1998. Since construction of the Woolston Cut and the tidal control stopbanks (RL10.8m) the Heathcote River tidal and flood flows were mostly contained within the riverbanks.

The local stormwater drainage network within the areas adjacent to the river consists of both road drainage and large catchment drainage such as Tennysons Drain. Drainage outfall diameters range from DN150 to above DN2100. Some outfalls in the lower reaches have flapgates to prevent river and tidal backflow. Local sumps and gravity piping to the Heathcote River with double flapgates, installed in some areas to prevent river and tidal backflow, historically protected Lower Heathcote properties.

Although flooding had previously been experienced in the catchment, a number of residents in the area indicated that there had been no previous flooding on their properties prior to the earthquakes (CCC Task Force, 2014b). After the earthquake sequence, it is fairly common for riverside properties in this catchment to experience shallow flooding or have restricted access during large rainstorms. Three severe rain events from March 2014 to April 2014, have resulted in the recent floor level flooding in the area, along with widespread road, property, and ancillary buildings flooding. Figure 8-5 shows flooded areas from the March 2014 event.

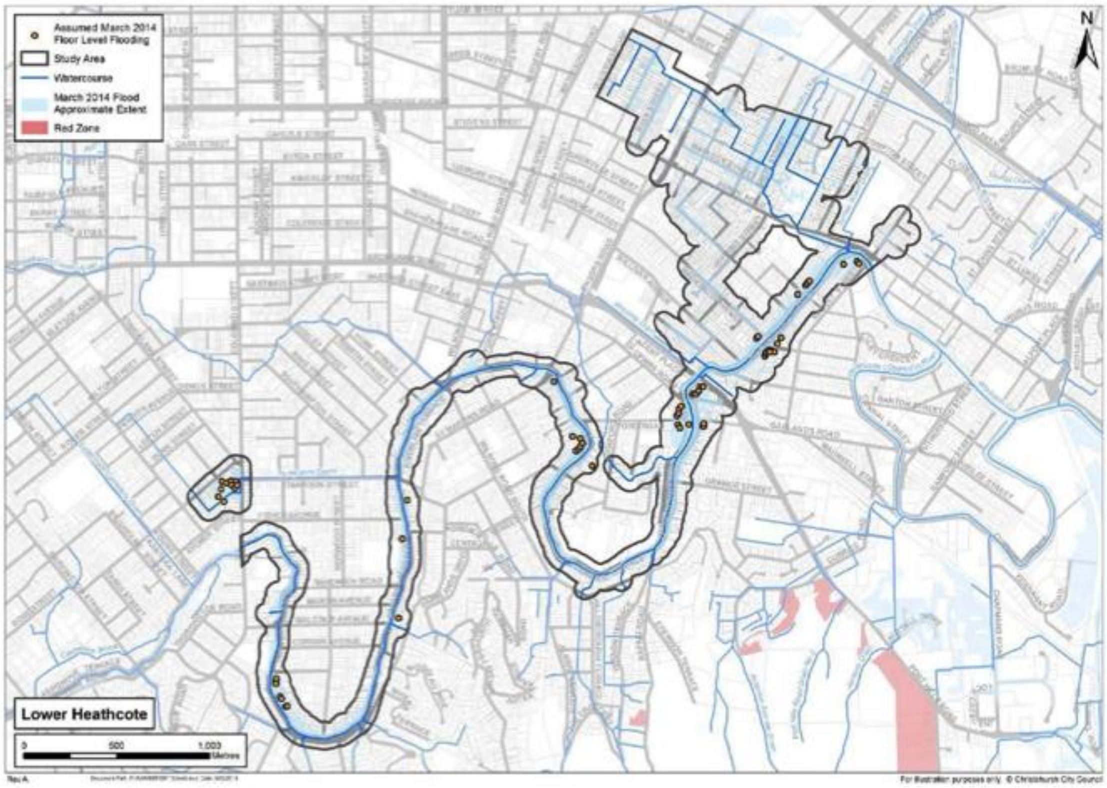

Figure 8-5 Lower Heathcote: boundary of the area analysed by the CCC Taskforce; extent of March 2014 flood and location of flooded houses (map from CCC Task Force 2014b).

Earthquake-induced tectonic-geotechnical effects and impacts on drainage and key infrastructures

LiDAR mapping from CERA (2014) indicates that there has been both land uplift and settlement over the Lower Heathcote Area. The Lower Section of the Heathcote River is tidally influenced and is reported to have risen by up to 400mm, while the upstream portion of the river has settled by 100-300mm. This has resulted in a flatter hydraulic grade reducing the hydraulic capacity of the River and leading to increased bed levels. The River is beginning to re-establish lower inverts in the downstream section.

The Heathcote River has sustained earthquake damage with lateral spreading, siltation and bed heave reducing the capacity of the river system. Surveys undertaken between Garlands Road and Radley Street in May 2014 indicates that there has been some localized reduction in tide bank heights; the design level for this bank (1986) was set at 10.9 mRL, however the survey indicates that approximately 20% of the banks have lower levels than designed, with some areas now having a level as low as 10.4 m RL.

Recent rock movement, slope cracking and slumping in the Port Hills has resulted in additional silt loading on the River and consequentially increased bed levels. The area also had extensive liquefaction and pipe damage (wastewater and stormwater), which has resulted in additional silt and sand loading.

Condition assessment reports indicate more damage to the stormwater network closer to the Heathcote River and on older drainage systems. Some wastewater repairs have been undertaken. However stormwater drainage repair is still in construction or planned within the next three years, these are mostly repairs and relays of existing pipe capacities.

SCIRT assessment of the drainage infrastructure indicated that there was some damage to outfall pipes. This damage is currently being assessed and some of the outfalls are highlighted for repair. The drainage outfall flapgates are in need of maintenance and residents indicate that backflow is the primary cause of flooding in some areas of the downstream section of the River, indicating that the valves are not operating as designed.

March 2014 flood extent

A moderate to high intensity rainfall over more than 24 hours caused flooding from the 5 March 2014 storm. However, 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. Residents reported the flooding initially came from the street sumps indicating the flap gates no longer operated correctly. Visual inspection of the flap gates indicated that they no longer fully closed and allowed the river water to backflow into the drainage system.

The storm coincided with a storm surge nearly 0.5 m above the expected tide elevation due to barometric and wind set-up effects. This combined with earthquake repairs in several streams (namely the Colombo Street Bridge) and sewer repairs in the Lower Heathcote caused higher flood levels in these rivers. In summary, tidal influence and local rainfall intensity and localised stormwater flooding (due to inability of stormwater to enter the river) were the main causes of flooding during the 5th March event in the Lower Heathcote area. As seen in Figure 8-5, river flooding was seen along the lower reaches of the Heathcote River and the streets adjacent to the river banks.

March 2014 flood impacts on the built-environment

Flooding depths varied along the length of the Heathcote River; depths were anecdotally recorded from 300 -1000mm on properties. 19 properties were identified as flooded ‘Above Floor Level’ in the Lower Heathcote area. However, LiDAR contour maps predict that unrecorded flooding exists in the same area.

Flooding ‘Above floor level’ has resulted in damage to houses and contents. Property damage includes flooding of cars and garages.

The flood depth on the road corridor was too deep for vehicle passage and resulted in isolation of residents. Restricted access to property increased the feeling of vulnerability among residents.

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