The 2017 Port Hills wildfires – a window into New Zealand's fire future?

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Abstract

The Port Hills fire of February 2017 was New Zealand's most devastating wildfire of recent times. Occurring on the outskirts of Christchurch city, it burned 1660 hectares, destroyed 9 homes and damaged 5 others, and resulted in the evacuation of more than 1400 residents from 450 households. If it were not for the efforts of firefighting agencies, the losses could have been very much greater. It is however worrying, when considered in the context of other significant rural-urban interface wildfires during the 2016/17 fire season, the trend of increasing house loss in New Zealand, and projections for future fire risk with climate change, that the Port Hills wildfire could become the norm that New Zealand fire agencies have to deal with. Now is the time to re-think the use of planning controls and homeowner education to mitigate future fire losses at the rural-urban interface.

Keywords: *wildfire risk, rural-urban interface, house loss, New Zealand*

While not the most fire prone country in the world, New Zealand still has a history of significant wildfires (Guild & Dudfield, 2010; McLean, 1978; Pearce, Dyck, Frampton, Wingfield & Moore, 2000). Currently, 4,100 fires burn around 5,500 hectares of forest and rural lands each year (National Rural Fire Authority, 2015; Anderson et al., 2008). The majority of fires are small, averaging less than one hectare, but occasional large wildfires can be much more devastating. The Port Hills wildfire of 13-16 February 2017 in the hill suburbs of Christchurch city was one such event. Originating from two fires that subsequently merged, the fire destroyed 9 homes and damaged 5 others (Australasian Fire and Emergency Services Council , 2017), and resulted in the evacuation of at least 1,400 residents from 450 households (Stuff, 2017a). Tragically, a helicopter pilot also died while fighting the fire. In total, the fire burned 1,660 hectares, and cost NZD $7.9 million to suppress (Hayward, 2017), with insurers paying out at least a further NZD $17.7 million in claims (Radio New Zealand, 2017).

The 2017 Port Hills wildfire is an example of the increasing worldwide trend of wildfires impinging on urban areas, and increasing risks to lives and property (Langer & Wegner, 2018). Such fire events are not new to New Zealand (Bennett, 1999; Fogarty, 1996; Pearce, 1994; Pearce, 2001), but have occurred relatively infrequently and, up until 2017, involved the loss of few properties or fatalities. During the 2016/17 fire season, however, the occurrence of the Port Hills wildfire and a number of other *rural-urban interface* (RUI) fire events, in areas where urban development overlaps with flammable vegetation, resulted in over 30 homes being damaged or destroyed. This was the greatest number of homes destroyed in almost 100 years (Langer, McLennan & Johnston, 2018). With the risk of wildfires also likely to increase in future (Pearce & Clifford 2008, Reisinger et al., 2014), we are also likely to see greater fire impacts at the RUI.

The issues associated with the international equivalent of RUI fires, *wildland-urban interface* (WUI) fires, are well known and options for mitigation widely understood (Cohen, 2000; Gale & Cortner, 1987; Fogarty, 1995; Mell, Manzello, Maranghides, Butry & Rehm, 2010), at least by fire and land management agencies. These include planning controls on building siting and construction, and increased homeowner awareness and education on property fire risk mitigation activities such as fuels management and maintenance of *defensible space*, a zone around a building where vegetation has been modified or cleared to increase the chance of it surviving a wildfire.. However, despite this, homes and lives continue to be lost in WUI fires. In part, this is due to the complex social issues about why people choose to live in fire prone areas, how they perceive wildfire risk, especially relative to other risks, and their willingness and capability to undertake mitigations

– either individually, collectively as communities, or in partnership with fire and other land management agencies (McCaffrey, 2015); Toman, Stidham, McCaffrey & Shindler, 2013.

The devastating 2017 Port Hills wildfire, and other similar RUI fire incidents from recent fire seasons, should serve as a major prompt to fire agencies, local councils and property owners alike in New Zealand - of the need to raise awareness of RUI fire issues, and increase education and guidance for at-risk communities, concerning options for mitigating wildfire risk. Perhaps more importantly, they should also prompt a significant review of the treatment of wildfire risk in local planning processes across the country. This should include the need to better identify wildfire prone areas, and to include stronger controls on development and construction, alongside the provision of defensible space in these high fire risk areas.

The development of the Port Hills wildfire, subsequent response to the fires, and fire environment in which they burned is well documented in the Operational Review report on the fires, by the Australasian Fire and Emergency Services Council (AFAC) (2017). However, for the purposes of the discussion that follows, and for associated papers in this Special Issue, brief synopses are provided below.

Fire chronology

The Port Hills wildfire began as two separate fire events. The first, known as the Early Valley Fire, was initially reported at 5:44 p.m. on Monday, 13 February 2017, on the road verge on the south side of Early Valley Road, Lansdowne. This location is shown in Figure 1, which is a re-drawn version of the figure appearing page 20 of AFAC (2017), using FENZ and Scion data. This fire spread rapidly upslope through gorse and grass vegetation under the prevailing north-westerly winds, towards Summit Road. Several properties had to self-evacuate, while residents from one home had to be evacuated by helicopter because the fire was rapidly approaching. By 6:40 p.m., approximately 1 to 1.25 hours after ignition, the head fire had travelled approximately 1.5 kilometres, damaging three homes and destroying another. It was still running up the ridge to the southeast and flanking to the north and south into pasture, gorse and pine plantations, threatening more homes.

The second fire, some four kilometres to the north, was reported around 90 minutes later, at 7:11 p.m. It was burning in scrub vegetation on the city side of Summit Road, southwest of the Sign of The Kiwi near Dyers Pass, as shown in Figure 1. Known as the Marleys Hill Fire, it initially burned uphill through grass and tussock to the southwest, and west downslope into pine forest adjacent to the Christchurch Adventure Park. Several homes at the top of Worsleys Spur, as well as communications infrastructure on Marleys Hill were initially threatened, together with the forestry plantations.

Both fires continued to burn into the evening with helicopters and ground crews working on containment. At around 9 p.m. the helicopters were stood down due to the lack of light. By this stage, the Early Valley fire had travelled around three kilometres and covered approximately 230 hectares (Cowan, 2017a). Two more houses were surrounded by flames and, within the next few hours, one was destroyed and the other damaged.

Overnight and into the next morning, Tuesday, 14 February, the Early Valley Fire jumped Summit Road and burned around the Cass Peak radar facility. It began spreading downhill, towards the Allandale/Ohinetahi area of Governors Bay above Lyttelton Harbour. During the same day, the fire on the cityside of the ridge continued flanking to the north into the upper Hoon Hay valley. Considerable suppression effort was focussed on keeping it from spreading through the valley bottom into plantation forest and from running upslope to join up with the Marleys Hill Fire.

The Marleys Hill Fire continued burning mainly downslope overnight through pine plantation, and by mid-morning, at 11.25 a.m. on Tuesday, had a length of about one kilometre and covered approximately 28 hectares (Cowan, 2017a). Suppression was focussed on stopping the fire from spreading beneath the gondola facility of the Adventure Park. This included the use of fixed-wing retardant drops, which successfully held the fire back for many hours, before it eventually burned around the retardant line.

In the early hours of Wednesday, 15 February, the Early Valley Fire made a downhill run towards properties in the Allandale area, requiring urgent evacuations. In contrast, the Marleys Hill Fire grew little overnight. Shortly after 10 a.m. Wednesday, a significant wind shift to the northeast caused the two fires to join. The combined fire began a series of downslope runs towards the hill suburbs above the city, causing widespread evacuations. By 1 p.m.,

the merged fire covered an area of approximately 1,000 hectares and had a perimeter of 40 km (Cowan, 2017a), and was sending thick smoke into the city.

Over the next 4.5 hours, under the influence of strong east to north-easterly winds, the fire pushed down the Dyers Pass/Cracroft and Hoon Hay valleys, and then to the southwest. In a series of devastating cross-slope runs through Worsleys Spur above Westmorland, it spread towards homes in Kennedys Bush subdivision, and south into the Lansdowne area. Three homes were destroyed on Worsleys Road, and another two in Hoon Hay Valley. Around 6:30 p.m., a fire run from the Hoon Hay Valley burnt over the spur back into Early Valley, destroying another home.

The fire continued burning actively through Wednesday night, and was highly visible from the city. Jumping Dyers Pass Road, it spread through the top of Victoria Park, causing further evacuations in the Cashmere Hill suburbs and threatening the Sugarloaf transmission tower. Early on the morning of Thursday, 16 February, flare-ups along Worsleys Road caused one last house to be lost and another to be damaged.

By late Thursday, the fire had effectively stopped spreading. Only small areas of growth were reported over subsequent days. The fire was finally declared out more than two months later. The final area burned was 1,661 hectares, and the fire had claimed nine homes and damaged five others (AFAC, 2017). In addition, the fire had caused the evacuation of at least 450 households with an estimated 1,400 residents (Stuff, 2017a), many

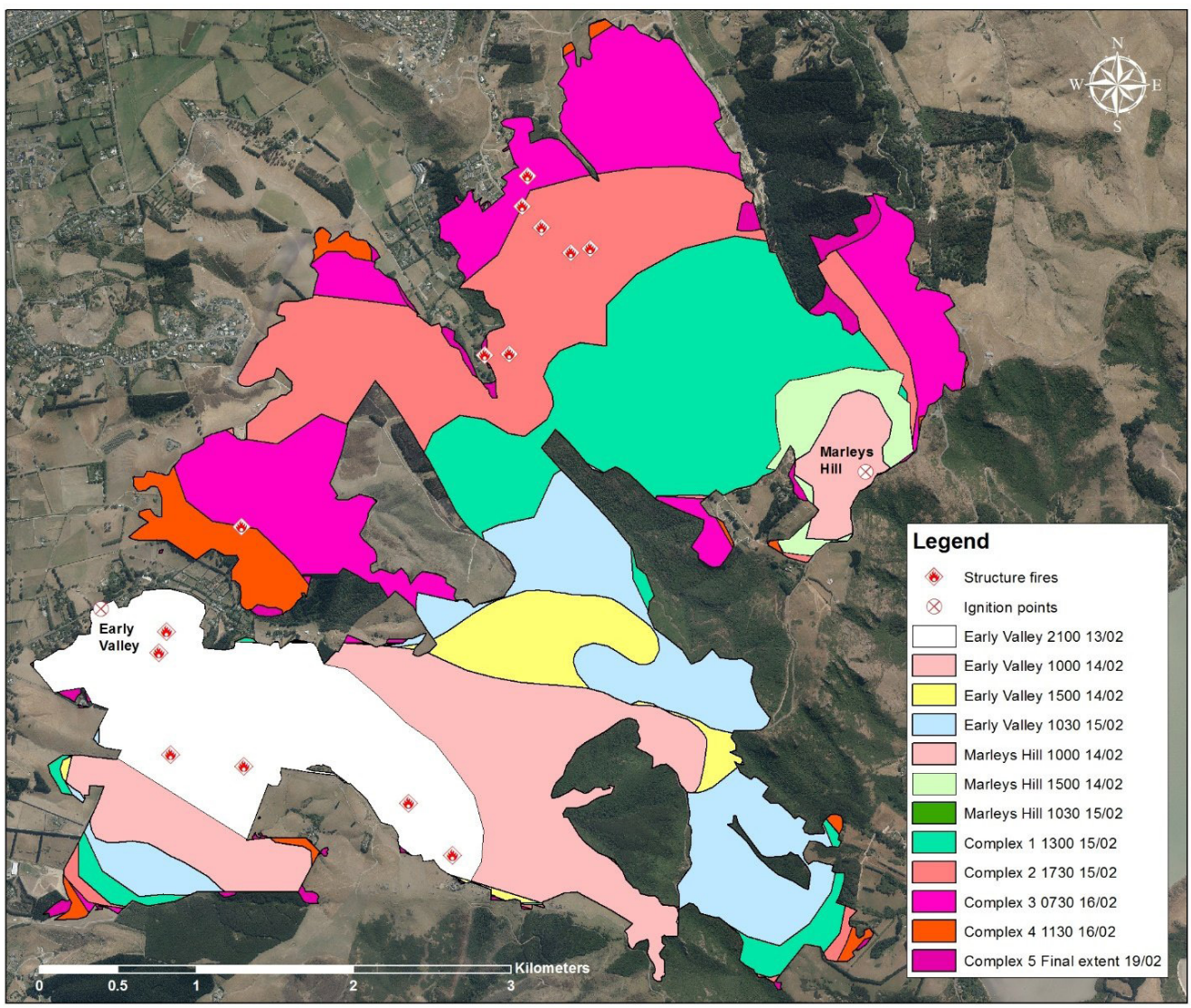

Figure 1. Progression in growth of the 2017 Port Hills wildfire over the first five days. Colours indicate fire growth reported for different time periods. Red diamonds indicate the location of destroyed or damaged homes.

of whom were away from their homes for up to a week. Fortunately, no residents were injured or killed, although tragically, a helicopter pilot was killed while fighting the fire.

Fire jurisdiction

The Port Hills wildfire occurred prior to the merger of urban and rural fire agencies into the single Fire and Emergency New Zealand (FENZ) organisation, which came into effect only a few months after the fire on 1 July 2017. Prior to this, rural fire control came under the responsibility of Rural Fire Authorities, comprising local territorial authorities, being district and city councils, and the Department of Conservation, the NZ Defence Force, and forestry-based Rural Fire Districts.

The Early Valley fire occurred within the jurisdiction of the Selwyn District Council (SDC) Rural Fire Authority, whereas the Marleys Hill fire fell within the jurisdiction of the Department of Conservation. This was further complicated by both fires subsequently spreading into the neighbouring Christchurch City Council (CCC) Rural Fire Authority's area of responsibility, and also threatening to spread to properties within the Christchurch City urban fire district. The New Zealand Fire Service's urban resources provided the initial response to both fires. They soon after handed over command to each appropriate Rural Fire Authority, while continuing to provide firefighting support. An overview of the initial and extended response to the fires is included in the Operational Review report on the fires (AFAC, 2017).

Firefighting resources and personnel were provided during the Port Hills wildfire by a wide array of agencies, including permanent and volunteer urban fire brigades from the NZ Fire Service, and staff, volunteer rural fire forces and contractors from Selwyn District and Christchurch City councils, and from the Department of Conservation and the NZ Defence Force. Incident management team personnel were also provided by these local fire authorities, plus the National Rural Fire Authority (NRFA), NZ Fire Service and other Rural Fire Authorities across the country. In some instances, especially during the early stages of the fire, farmers and landowners also used their own firefighting equipment and heavy machinery contractors, external to the official response (Macfie, 2017; Wall et al., 2017). In total, more than 300 firefighters from across the South Island, 14 helicopters and over 100 appliances and water tankers were deployed (FENZ, 2017a).

In response to the widespread public evacuations, a Civil Defence emergency was also declared on the afternoon of Wednesday, 15 February. While some debate resulted around the timing, particularly the lateness, of this declaration (see for example: Truebridge & Law, 2017), it was considered to have had little effect on the fire suppression efforts (AFAC, 2017). However, it resulted in greater resource commitment to management of the evacuations and associated cordons, and to the dissemination of public information (AFAC, 2017).

Fire causes

The cause of each of the fires was not able to be definitively identified. The Early Valley Fire was initially attributed to a powerline fault, however this was eventually discounted, and both fires were determined to be suspicious. Based on the information available, FENZ believed the Marleys Hill Fire to have been deliberately lit, and the Early Valley Fire to be either accidental or also deliberately lit (FENZ, 2017b).

Research suggests that wildfire arson and malicious lighting of fires are much more prolific in New Zealand than official statistics suggest (Hart & Langer, 2011). New Zealand fire managers also widely consider that malicious fire starts including arson, are a growing problem and are very difficult to stop, despite potential preventative actions that include interagency information sharing, mapping and intervention schemes (Hart & Langer, 2011).

Other common causes of fires in rural-urban interface areas include accidental fire starts, such as sparks from mower blade strikes, escapes from rubbish burning, fireworks and children playing with matches. Causes also include vehicles and powerlines. Jakes, Kelly and Langer (2010) and Hart & Langer (2011) reported that the owners of RUI properties, including the residents of lifestyle blocks, have often been unaware of rural fire risks, unprepared for wildfire and more likely to cause fires as a result, compared to long-residing rural landowners/farmers. In fact, a range of audiences can be identified with different requirements for fire risk information, depending on their use of and experience with fire (Hart & Langer, 2014; Langer & Hart, 2015).

Fire environment and associated fire behaviour

The fire environment of the Port Hills area is well documented by AFAC (2017) and by Cowan (2017b). The fire area comprised well-cured, 80-100 percent

dead, grass fuels. These were interspersed with areas of gorse scrub, pine plantations, and regenerating native scrub and forest. The latter was less flammable and for the most part aided fire suppression efforts. However, the patches of gorse scrub, many of which had been sprayed for weed control, contributed significantly to fire spread and intensity and the difficulty of controlling the fire - particularly during initial stages of the Early Valley fire. The combination of these flammable fuel types with the moderately steep slopes of the Port Hills, and prevailing north-westerly winds on February 13, meant that the Early Valley Fire developed and spread rapidly uphill towards the summit of the hills. Fire spread rates of 15-30 metres per minute, or 1-2 kilometres per hour, and head fire intensities of 15,000 to 35,000 kilowatts per metre, which correspond to flame lengths in the order of 6-10 metres, were estimated during these early stages (Cowan, 2017a). The Marleys Hill fire ignition occurred in a sheltered location, initially spreading more slowly uphill into the wind at 1-10 metres per minute with 300-15,000 kilowatts per metre fire intensities. It also backed downslope beneath pine plantation at 0.5-1.0 metres per minute, with intensities of 500-2,500 kilowatts per metre (Cowan, 2017a). The upper limit for successful fire suppression using conventional means, including heavy machinery and aircraft, is a fire intensity of 4,000 kilowatts per metre and flame length of approximately 3.5 metres (Alexander, 2000). This places the main fire spread of both fires outside of the realm of suppression.

The seasonal conditions prevailing at the time the fires broke out were moderately dry, but were by no

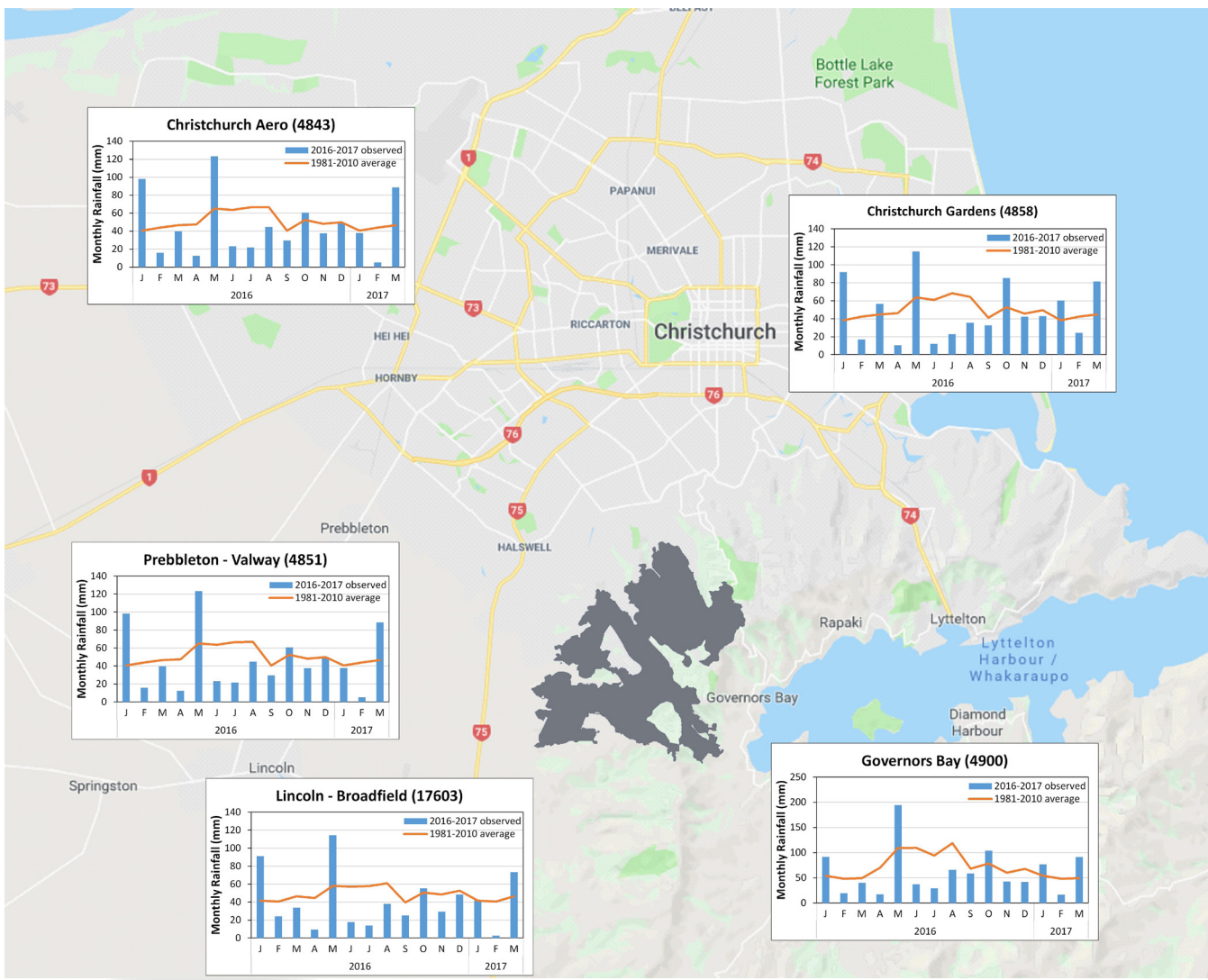

Figure 2. Comparisons of monthly rainfall patterns for weather stations close to the Port Hills wildfire area during 2016 and early 2017: Christchurch Aero (agent number 4843), Christchurch Gardens (4858), Prebbleton-Valway (4851), Lincoln-Broadfield (17603), and Governors Bay (4900). Bars indicate observed monthly rainfall totals, whereas lines indicate the long-term climatological monthly averages (30-yr normal for 1981-2010). Data extracted from NIWA National Climate Database (CliFlo).

means severe. In fact, with the exception of the weeks immediately before the fires, rainfall had been near average during January 2017 and December 2016, below average in November 2016 and above average in October 2016, as shown in Figure 2. A short dry spell of around 20 days occurred at most rainfall stations during late January and early February 2017, in which little or no rainfall was recorded. However, small amounts of rain were reported at many nearby locations on the morning the fires broke out. Temperatures (19-23 °C) and relative humidity (20-40%) over the first few days of the fires were also not exceptional for this region in mid-summer, although the wind strengths (10-40 km/h) were moderately strong, especially with the easterly change on February 15.

The brief dry spell prior to the occurrence of the fires had contributed to the declaration of a Prohibited Fire Season, or total fire ban, by the CCC Rural Fire Authority on 11 February, although the SDC Rural Fire Authority area remained in a Restricted Fire Season, with fire permits required, at the time of the fires (AFAC, 2017). Fire danger ratings for weather stations nearest the fire area, from components of the New Zealand Fire Danger Rating System (NZFDRS) used by New Zealand fire managers to monitor fuel dryness and fire behaviour potential (Anderson, 2005), were showing High to Very High fire dangers for grassland and forest fuel types at noon on the February 13. Due to the presence of stronger winds, Extreme fire dangers were showing for the February 14 and 15. Averaged values from the three closest stations (Motukarara, Christchurch Aero and Bottle Lake) / AFAC, 2017) for the first three days of the fires, when most of the damage occurred, are shown in Table 1.

While relatively high, categorised as *Extreme* by the Forest fire danger class criteria of Alexander (2008)[1] and above average for the time of year, these fire danger ratings are well below the maximum values recorded for this region of the country, based on over 40 years of data for Christchurch Aero up to 2002 (Pearce et al., 2003). They are also

Table 1.
Averaged Values from the Three Closest Stations

	13/02/2017	14/02/2017	15/02/2017	Feb. avg.	Feb. max.
Fine Fuel Moisture Code	87	92	93	85	98
Duff Moisture Code	65	69	72	40	164
Drought Code	555	562	569	458	795
Initial Spread Index	7	16	13	8	116
Buildup Index	100	105	109	64	211
Fire Weather Index	24	44	38	19	123
Fire Danger Class	High/V. High	Extreme	Extreme		

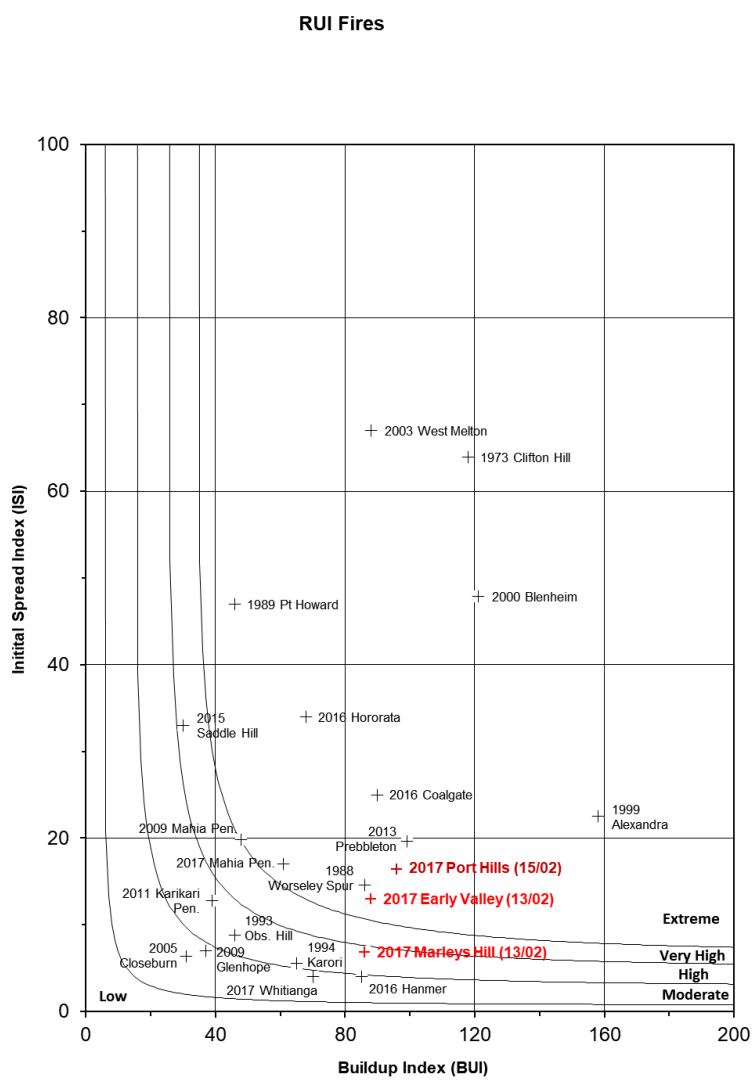

Figure 3. Fire danger ratings for the Port Hills fires, and other recent New Zealand rural-urban interface wildfires involving property damage and/or significant evacuations. Data from Scion, and Pearce (1994).

1 Very high and Extreme fire danger days can be created by either dry conditions resulting from lack of rainfall (such as short or long term drought) or strong winds (often in combination with high temperatures and low humidity), or a combination of both. In the case of the Port Hills wildfire, they occurred through the combination of a short dry spell (~20 days) together with strong winds on the days the fires broke out (Feb. 13-14th, northwesterly) and intensified (Feb. 15th, change to northeasterly).

well below those experienced during many previous RUI wildfires in New Zealand, including several in Canterbury and on the Port Hills (e.g. 1973 Clifton Hill, 2003 West Melton, 2016 Hororata). This is shown in Figure 3.

Together with the other fire environment components of fuels, terrain and weather, the underlying fire danger conditions did contribute to the extreme fire behaviour[2] observed during the fires. As well as the rapid upslope rates of fire spread observed in the hours after the Early Valley fire ignition, both fires also exhibited rapid downhill spread rates on several occasions. This included the downslope run towards Governors Bay in the early hours of the February 15, when overnight weather conditions and the downhill spread direction would normally dictate less intense fire behaviour. This unusual activity is believed to have been the result of downslope *katabatic* airflow, resulting from cooling air descending towards the harbour, potentially in combination with the night-time land breeze towards the ocean (Pretorius, Sturman, Strand, Katurji & Pearce, n.d).

Rapid downhill fire spread was also observed following the merging of the fires and subsequent *blow-up*, or intensification, on the afternoon of the February 15, when the fire spread downslope towards the city and then, with the easterly wind change, spread rapidly cross-slope. Observed spread rates during this latter period were estimated by the author to be in excess of 60 metres per minute, or 3.6 kilometres per hour, through fully cured grass fuels above homes in Kennedys Bush. Fire whirls and a possible fire tornado were also observed during the fire's blow-up (Northcott, 2017), although the occurrence and scale of the latter is still debated. The meteorological conditions contributing to the fire spread, and the fire blow-up, apparent fire tornado and observed shearing of the smoke column on the February 15, were investigated in detail by Pretorius et al. (n.d.). A key finding was the absence of longer term seasonal influences on the occurrence of the fires, and that the hot, dry conditions immediately prior to the fire and during the fire itself were associated with short-term, synoptic weather systems.

2 Extreme fire behaviour (as opposed to extreme fire danger) represents unpredictable fire activity including rapidly increasing fire spread and intensity, or characteristics such as crown fires, fire whirls or ember spotting. Extreme fire behaviour can occur on small or large fires and, depending on the fuel type, terrain and weather conditions, at any level of fire danger. It is highly dangerous and cannot be suppressed using conventional fire suppression methods (Werth et al., 2011).

Discussion

The Port Hills wildfire was not the largest or most extreme wildfire that New Zealand has seen in recent decades. Larger fires have occurred previously, including the Wither Hills fire on the outskirts of Blenheim on Boxing Day 2000, which burned 6,159 hectares and damaged 17 rural farm properties, two lifestyle properties and the Council-owned Wither Hills Farm Park recreation area and forestry block (Graham & Langer, 2009; Pearce, 2001). The 1999 Alexandra fires burned a total of 8,200 hectares, predominantly in two major fires near Roxburgh (5,600 ha) and Clyde (2,600 ha). The latter Springvale wildfire was responsible for the majority of the property damage, destroying two houses and numerous outbuildings, threatening the town of Alexandra and causing the declaration of a civil emergency and evacuation of some 80 homes (Bennett, 1999; Pearce, 1999). Both of these fire incidents occurred under much higher fire danger conditions, shown in Figure 3, and burned considerably larger areas. Conversely, the Port Hills wildfire resulted in the greatest reported property loss in an individual fire in almost 100 years; since the 1918 Raetihi Fire when 120 houses, 60 commercial premises and 9 sawmills were destroyed, 3 lives were lost and many people were severely burned (McLean, 1992). The Port Hills wildfire also occurred during a fire season when there were a number of other RUI fires that resulted in significant property loss, with at least a further seven houses lost and several damaged, in addition to many outbuildings.

The Port Hills wildfire, and these other 2016/17 RUI fires, provide a window into the future, in which New Zealand is likely to see many more similar fire incidents. Research (Pearce et al., 2005; Pearce & Clifford 2008; Pearce et al., 2011) has shown that fire risk in New Zealand will increase with climate change, due to higher temperatures, reduced rainfall and stronger winds in many areas. Like other parts of the world, these rising fire dangers combine with growing population and expanding urban areas to result in an increased number of wildfires, including larger fires potentially impacting on communities (Reisinger et al., 2014). Analysis of even recent history shows a clear trend of increasing RUI fire incidents in New Zealand, and also of associated fire impacts including homes lost, damaged, threatened and evacuated, as shown in Figure 4.

The risk of RUI wildfires is not a new phenomenon. It has been widely known for many years, both internationally

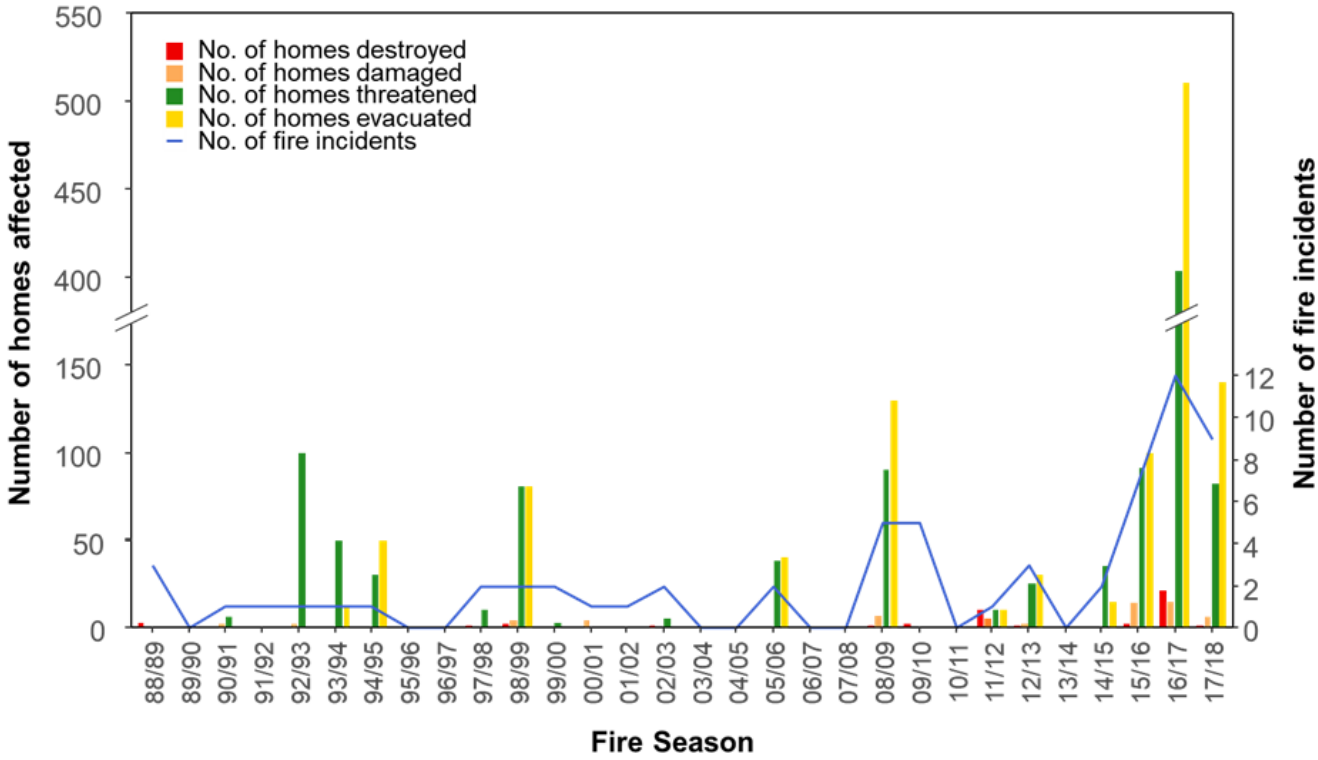

Figure 4. Trends in reported rural-urban interface (RUI) fire events, including number of RUI fire incidents (line graph), and numbers of homes destroyed, buildings damaged, homes threatened and homes evacuated (bars) by fire season (from 1988/89 to 2017/18). Data from Scion.

(Butler, 1974; Gale & Cortner, 1987) and in New Zealand, for example as documented by Anonymous (1982) and the Forest and Rural Fire Association of New Zealand (FRFANZ)(1994). Fires like the Port Hills wildfire should therefore not come as a surprise. The RUI, or WUI as it is referred to internationally, has been defined as those areas where houses mix or intermingle with potentially flammable vegetation, which can be further divided into: the *interface*, areas where buildings are in close proximity to large contiguous patches of flammable vegetation; and the *intermix*, areas where buildings are interspersed within flammable vegetation (Radeloff et al., 2005). The close proximity of buildings to flammable vegetation increases fire risk on two fronts: first, there are likely to be more wildfires due to human ignitions; and second, fires that do occur pose a greater risk to lives and homes (Radeloff et al., 2018). In an effort to guide wildfire risk reduction efforts, a number of methods have been developed for identifying the spatial extent of the RUI (Bar-Massada, Stewart, Hammer, Mockrin & Radeloff, 2013; Calkin, Rieck, Hyde & Kaiden, 2011; Chas-Amil, Touza & Garcia-Matrinez, 2013; Johnston & Flannigan, 2018; Lampin-Maillet et al., 2010; Radeloff et al., 2005; Theobald & Romme, 2007). Several of these methods have been tested in New Zealand (Pearce, Langer, Harrison & Hart, 2014). However, it is almost universally accepted that the area of RUI potentially prone to wildfire is growing, as population and associated demand for housing increase, and more people move out into rural areas (Kramer, Mockrin, Alexandre, Stewart & Radeloff, 2018; Radeloff et al., 2018). As a result, fires are also becoming more destructive and costly, according to Gude, Jones, Rasker and Greenwood (2013) and the Association for Fire Ecology (AFE)(2015).

Cohen (2000, p. 20) describes the RUI/WUI fire problem as essentially "a home ignitability issue". However, several factors determine the overall likelihood of building loss from wildfire, including building location, design, construction materials and maintenance, spatial configuration of flammable wildland vegetation, as well as suppression capabilities and response (Alexandre et al., 2016; Price and Bradstock, 2013; Radeloff et al., 2005; Syphard, Brennan & Keeley, 2017). This means that the RUI problem is more than just a home ignition problem. It is also a social as well as a physical problem, where a combination of efforts by fire and land management agencies, local government and private landowners at national, regional and local scales is needed to be most effective (Calkin, Cohen, Finney & Thompson, 2014), as shown in Figure 5. Tackling the

RUI fire problem requires a multifaceted approach that aims to reduce the risk of home loss by addressing both home exposure and susceptibility to wildfire through a range of actions, including home ignition zone management, planning controls, and traditional wildfire prevention, fuels management and response activities (Calkin et al., 2014). This figure shows how the risk of home loss is jointly determined by the probability of home exposure to wildfire and the susceptibility of homes to wildfire, which in turn are influenced by other factors. Actions and responsibilities for strategically managing risk factors vary across land management agencies, local government, and private landowners.

1. Wildfire prevention and management

The role of fire and land management agencies is to reduce the probability of home exposure to wildfire through the use of fire prevention measures, such as fire season restrictions and activity controls, which reduce the likelihood of fires occurring. They also have a role in readiness and response activities, to suppress wildfires when they do occur. Fuels management can also help reduce the chances of fire spread, and decrease potential fire intensity, thereby increasing the success of fire suppression while reducing the consequences or potential damage. At the time of the Port Hills wildfires, Councils were themselves Rural Fire Authorities with a lead role in rural fire management. This included fire prevention, fuels management and fire control. However, with the merger of New Zealand's rural and urban fire organizations, these responsibilities have now all transferred across to FENZ, including the management of hazardous fuels. While this is simpler in terms of being managed by a single agency, there have been concerns expressed regarding the separation of fire management from other land management functions (Dudfield, 2012), particularly a shift in focus to fire suppression and response at the expense of fire prevention and fuel reduction (Cheney, 2004; Stephens, 2010). Conflicts between fire management and other management objectives could also apply, as raised by Driscoll et al. (2010) and Fleming, McCartha and Steelman (2015). The centralisation of rural fire management into a single organisation (FENZ) also divorces it from the local and regional councils responsible for land use planning and hazard mitigation, which have had a key role in reducing the risk of RUI fires (Calkin et al., 2014).

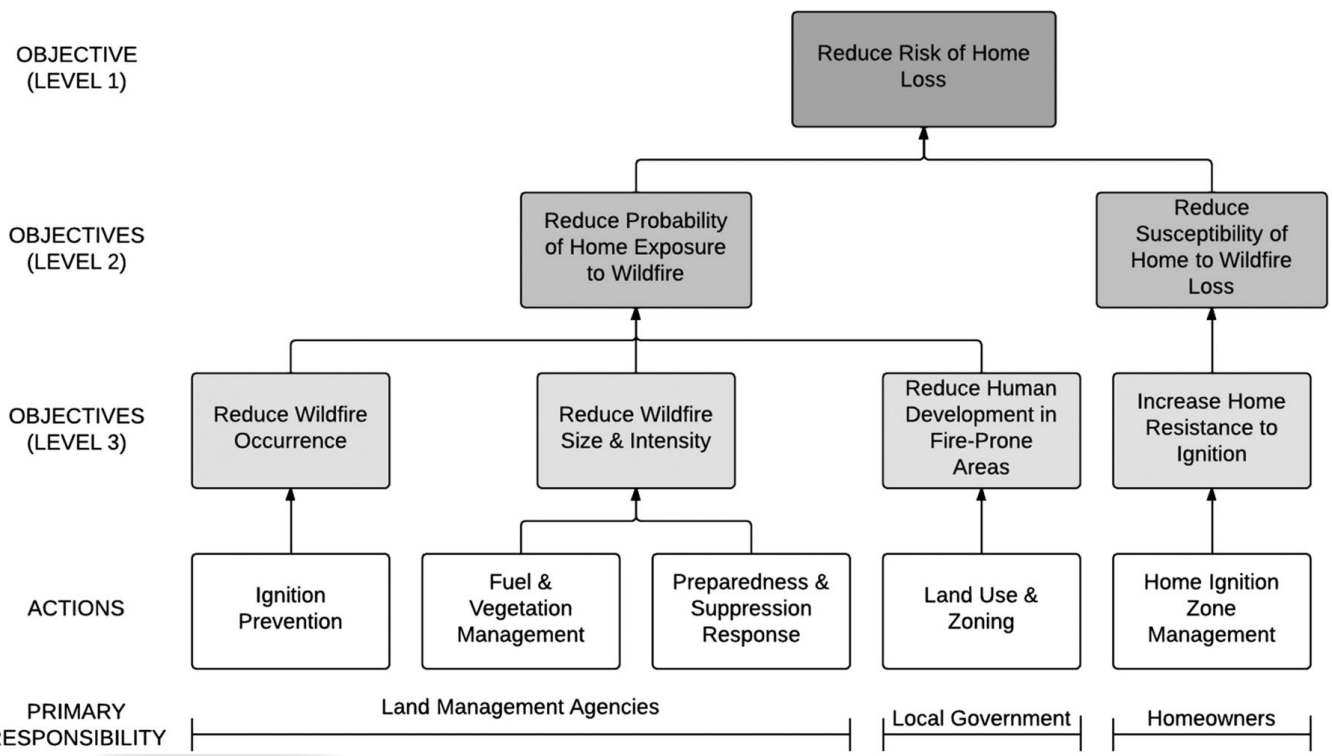

Figure 5. Conceptual model of objectives and actions for reducing the risk of home loss as a result of wildfire. From "How risk management can prevent future wildfire disasters in the wildland-urban interface" by D. E. Calkin, J. D. Cohen, M. A. Finney & M. P. Thompson, 2014, *Proceedings of the National Academy of Sciences of the United States of America, Volume 111,* p. 748. Copyright 2014 by the National Academy of Sciences of the United States of America. Reproduced with permission.

2. Planning controls

Fires such as the Port Hills wildfire clearly show that not all fires can be prevented, or controlled, before they impact on people and property. Hence there is a clear role for local government, with responsibility for local planning, to also utilise land use and zoning controls to reduce exposure to wildfires. In New Zealand, there were some early attempts to mitigate RUI fire risk through planning controls (Oliver, 1994; Twigg, 1994; Wellington Regional Rural Fire Committee, 1996). However, these attempts tended to focus on set-back distances from surrounding vegetation, access for emergency service vehicles and provision of water supplies for firefighting (Oliver, 1994; Twigg, 1994). Broader recommendations regarding construction materials, and more effective building and subdivision design did not become widespread until the more recent FireSmart community fire protection initiatives led by the NRFA and the NZ Fire Service (NRFA, 2004, 2006), but these have struggled to gain traction within local government (Hart & Langer, 2014; Pearce et al., 2014). Despite the fact that the SDC is more actively addressing this through its latest plan review (Love, 2018), neither of the Christchurch (CCC, 2015) or Selwyn (SDC, 2016) Operative District Plans at the time of the Port Hills wildfire contained specific provisions addressing wildfire risk - apart from those around provision of property access and water supplies for firefighting, and separation distances for residential buildings from forestry and farming activities.

More consistent application of planning controls for rural fire, as are now employed in Australia following the 2009 Black Saturday fires in Victoria through the designation of Bushfire Prone Areas (Pearce et al., 2014; VBRC, 2010), would provide more powerful tools for controlling building and, in some cases, preventing development, in the most fire-prone areas (Syphard et al., 2013). Wildfire risk is nonetheless still some way off being considered in the same way as other hazards, such as flooding or earthquakes in this regard (Charnley et al., 2015; McCaffrey, 2004). In New Zealand, this will require much greater recognition of wildfire risk by planners, and incorporation of the latest science around wildfire risk assessment from here and overseas into local planning processes. Glavovic (2010) and others (Crawford, Crawley & Potter, 2018; Glavovic et al., 2010a, 2010b; Saunders et al., 2007; Saunders & Kilvington, 2016;) have clearly outlined the benefits of natural hazards planning in New Zealand, but also the barriers to and priority actions required to realise its full potential for disaster risk reduction. Key to achieving this is the strengthening of links between planners and emergency managers (Saunders et al., 2007; Weir, 2013), in this case to fire managers and associated wildfire science knowledge. Weir (2013) provided an excellent review of approaches to bushfire planning in different jurisdictions in Australia, which highlighted opportunities as well as challenges. One of the challenges is the need to engage and involve communities in the planning process. The latter is by no means an easy task, especially because this requires an understanding of community composition (Carroll & Paveglio, 2016; Hart & Langer, n.d) and what they value (Beilin & Reid, 2015; Rawluk et al., 2017). Initiatives in the USA, such as Community Wildfire Protection Plans (CWPPs), have nevertheless been found to be very successful (Jakes & Sturtevant, 2013).

3. Home protection guidance

Homeowners living in wildfire-prone locations are able to minimise the risk that their house will be ignited and burn, by altering building characteristics and the vegetation around their homes (Calkin et al., 2014; Cohen, 2000; Fogarty, 1996). Many different agencies have developed guides on how to achieve this, both in New Zealand (NZ Fire Research, 2000; NRFA, 2004, 2006, 2009) and overseas (Country Fire Authority, 2012, 2017; National Fire Protection Association, 2008; Standards Australia, 2009;). However, these guidelines are rarely mandatory (McLennan et al., 2017; Schoennagel et al., 2009; Wolters et al., 2017), and instead voluntary efforts are promoted through fire outreach programs such as Firewise USA (National Fire Protection Association, 2018), Fire Adapted Communities (Fire Adapted Communities Coalition, 2018) and FireSmart (NRFA, 2006, 2009; Partners in Protection, 1999). At the time of Port Hills wildfire, such guidance was available to home owners; however, it was not being actively promoted by the NRFA or by the NZ Fire Service, who were ambivalent regarding the success of their existing FireSmart programme (NRFA, 2004, 2006, 2009) and were in the process of reconsidering their approach (Hart & Langer, 2014), as discussed in a 2014 NRFA workshop ahead of the FENZ merger.

Councils such as CCC and SDC, as Rural Fire Authorities prior to the FENZ merger, also promoted property fire risk guidance - mainly via fire season communications and website information (see for example: SDC, 2018). However, this was again largely left to home owners to seek out themselves. Immediately following the Port Hills

wildfire, affected property owners and other residents had a much greater level of interest in relevant material (Pearce, 2017; Teeling & Pearce, 2017), although it is uncertain how long this increased awareness will last (Champ & Brenkert-Smith, 2016). With risk reduction and community resilience now central to its strategic priorities, FENZ is currently in the process of developing guidance materials on wildfire risk and mitigation methods for rural and RUI residents (FENZ, 2018).

4. Homeowner fire preparedness

Whether with or without specific local government wildfire risk planning requirements, or fire agency and/or community-led fire risk reduction initiatives (such as FireSmart and FireWise), there is still an onus on individual homeowners to take some responsibility for protecting their property from wildfires. Adherence to planning requirements will not prevent all homes from burning down. Similarly, fire agencies cannot protect every property during a major event. Homeowners can and should undertake a number of relatively simple and inexpensive actions that will significantly reduce the chances of their home being burned in a wildfire.

As well as considering wildfire risk during the building stage, through house siting, design and use of fire-resistant construction materials, the concept of defensible, or defendable, space is a key factor in increasing house survival for either a new or existing property (Syphard et al., 2014; Kornakova & March, 2017). The presence of vegetation and other flammable materials within the area immediately around a home affects its likelihood of igniting from flame contact, radiated heat and also burning embers (Cohen, 2000). Therefore, removing or reducing the amount of flammable vegetation within a zone of at least 10-30 metres wide[3] around the home can limit fire spread and flame contact, and reduce radiated heat, significantly increasing the chances of house survival (Cohen, 2000; Wilson & Ferguson, 1986). This fuel-reduced zone also makes it safer for firefighters, or homeowners, to defend the property (Gill & Stephens, 2009).

The size and shape of the defensible space needed depends on factors such as slope, prevailing wind strength and direction, and nature of surrounding fuels. Guidelines, from the NRFA (2009) for example, often recommend two zones. These zones are made up of a priority zone closest to the home which is largely free of vegetation. The second zone is further away, where fuels are still present but have reduced density and canopy cover. Creating defensible space does not mean that all vegetation needs to be removed. A combination of cleared areas, like driveways and paths, and well-maintained lawns and gardens can provide effective protection. Key to the success of defensible space is regular maintenance to remove the build-up of dead material, including roof gutters where leaf litter can provide an entry point for ignition by windblown embers. Similarly, use of low flammability planting can significantly reduce fire spread and intensity in this home ignition zone. Considerable research (Fogarty, 2001; Hall, 2015; NZ Fire Research, 2000; Wyse et al., 2016) has been done on the flammability of both New Zealand native and exotic plant species, resulting in recommendations for planting in fire prone areas. The conclusions of this research were actively promoted following the Port Hills wildfire, by Carswell (2017), Johnston (2017) and Stuff (2017b).

A number of other factors, such as the role of insurance, evacuation policies, and warnings, both in the form of fire danger ratings and other messaging ahead of and during wildfire occurrence, also have a potential role in mitigating RUI fire impacts. These factors involve risk perception, risk-sharing and human behaviour elements. They further highlight how RUI fires are as much a social problem as they are a problem with the physical environment (Calkin et al. 2014; Gill & Stephens, 2009).

Conclusion

The February 2017 Port Hills wildfire was a devastating fire event, burning 1,660 hectares, causing the loss of a life, multiple homes, plus farming, forestry, conservation and recreational values. The number of houses lost in this fire were the greatest lost in a single fire event in almost 100 years. For this and other reasons outlined above, the 2017 Port Hills wildfire provides a clear warning for fire agencies concerning New Zealand's potential wildfire future, and how that future may be exacerbated by expanding rural-urban interfaces and climate change. A growing population, more people moving into areas of flammable vegetation, and increasing fire season severity are combining to produce more and larger fires, with greater potential to impact on lives and property. If more proof were needed, it is worrying that New Zealand already appears to be mirroring other parts of the world, with evidence of an increasing trend in house loss and associated RUI fire impacts in recent years.

3 Preferably greater, where space permits.

However, not all RUI fire incidents are due to fires as large as the Port Hills event. The 2016/17 fire season showed us that homes are also lost and lives threatened by smaller wildfire events as well. These incidents can occur in any season, and in almost any part of the country. New Zealand cannot wait until the next Port Hills-type wildfire event, or devastating fire season like 2016/17, to take more definitive action to reduce wildfire risk. New Zealanders increasingly need to learn to live with wildfire events. The RUI fire problem is not new, and options for risk mitigation are well known. Action is needed now, to increase awareness of wildfire risk amongst homeowners and planning agencies alike, to improve guidance to communities, and to strengthen the use of planning controls to mitigate future RUI fire losses. Reduction of RUI fire impacts will be most successful if it involves a combination of national and local planning initiatives, community engagement and sharing of risk ownership, alongside homeowner property protection activities. By raising the profile of wildfire as a natural hazard in New Zealand, and applying known solutions for mitigating RUI fire risk, the impacts of future RUI wildfires can be reduced.

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