CSIRO LAND AND WATER FLAGSHIP
www.csiro.au

Sheltering practices during bushfire

Raphaele Blanchi[1], Joshua Whittaker[2,3], Katharine Haynes[3,4], Justin Leonard[1], Kimberley Opie[1], Mark Holland[5], Stephanie Dreyfuss[1,6]

[1] CSIRO Land and Water

[2] Centre for Risk and Community Safety, RMIT University

[3] Bushfire and Natural Hazards CRC

[4] Risk Frontiers, Macquarie University

[5] Country Fire Authority

[6] University of Melbourne

Report EP158583

November 2015

Report to Emergency Management Victoria, Natural Disaster Resilience Grants Scheme

Australian Government

VICTORIA State Government

Citation

Raphaele Blanchi, Joshua Whittaker, Katharine Haynes, Justin Leonard, Kimberley Opie, Mark Holland and Stephanie Dreyfuss (2015). Sheltering practices during bushfire, CSIRO report to the Department of Justice.

Copyright and disclaimer

To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of CSIRO and the Department of Justice.

Important disclaimer

CSIRO advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, CSIRO (including its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

Acknowledgements

This project is funded by the Australian Government under the Natural Disaster Resilience Grants Scheme (NDRGS). In the State of Victoria, the NDRGS is facilitated by Emergency Management Victoria. We gratefully acknowledge all the people who contributed to this research. We thank Kathleen Hodgson from Emergency Management Victoria who helped facilitate the project. Grateful thanks to Dawn Hartog, Danielle Scorer, Angela Cook (Country Fire Authority) for their help gathering information on sheltering and for their useful comments. We would like to thank Steve Pascoe for sharing his experience and information on the 2009 Bushfires. We thank Jacqui England (CSIRO L&W) for her careful considerations of this report and the useful comments and suggestions she has provided. Many thanks to Fabienne Reisen (CSIRO O&A) for providing information on air toxics. We acknowledge Australasian Fire Authorities Council and the Bushfire and Natural Hazards CRC that provided permission to use the data collected during the BCRC Research Taskforce 2009 bushfires survey.

Foreword

This report depicts events relating to bushfires in Australia and includes firsthand accounts, which some people may find distressing.

Executive summary

This project aimed to examine circumstances and challenges experienced by residents when sheltering during bushfires in order to establish an evidence base to support policy reform and community education initiatives. To address this, this report presents: 1) a review of sheltering practices in Australia and 2) the results of a qualitative and quantitative investigation of people's experiences while sheltering during the 'Black Saturday' bushfires on 7 February 2009.

Key findings:

The literature review focused on Australian research due to Australia's unique approach to community bushfire safety and sheltering.

- Studies of Australian fatalities over the last century show that more than half of all civilian bushfire deaths occurred outside while residents were attempting to leave or defend a property. However, recent studies show an increase in the number of fatalities resulting from sheltering inside a structure.
- Some previous studies highlight the importance of using several strategies for community safety to take account of the specificity of the risk and potential impact of fire under different weather conditions. These studies also recognise that people may shelter by choice or necessity.
- Research on resident planning, preparation and response identifies a number of factors and circumstances that may increase the risk of residents needing to take shelter during a bushfire. Residents who wait until the last moment before taking action are more likely to be forced into dangerous responses including late evacuation, untenable defence and passive shelter in an unsafe structure.
- Building vulnerability may also influence sheltering outcomes. Regarding house preparation, the emphasis has been on construction standards that focus on the reduction of ignition likelihood, with little discussion of how building design supports the sheltering process. In addition, there is little research on people's compliance with these measures or their preparation and maintenance to sustain house survivability.

Results from analysis of the 7 February 2009 bushfires

- Only a small number of interviewees intended to shelter as their primary strategy. In most cases, residents described their intention to shelter as a backup if their attempts to defend were unsuccessful. Only a small number of people had a contingency plan.
- Those who intended to stay and defend were more likely to have considered the need for shelter, often envisaging they would shelter inside during the main passage of the fire front and then exit the house to continue defending when it was safe to do so (as advised by fire agencies).
- Only a small number of residents planned specifically for what they would do if they needed to take shelter, and even fewer identified places they could go if they were unable to shelter inside the house. Most residents who sheltered undertook preparations with the primary aim of assisting them to stay and defend or leave. Few prepared specifically for sheltering prior to the bushfires; however, once the fires had started, many filled baths, sinks and containers with water, covered windows and wore protective clothing.
- For those who intended to defend, the main triggers for taking shelter were the sudden arrival of the fire front (including radiant heat, flames, embers, wind and noise).
- People sought shelter in a range of locations and shelter types. People most commonly sheltered inside houses (60%, including 113 fatalities and 496 out of 838 survivors) and around 12% sheltered inside commercial buildings such as hotels, pubs, wineries and ski huts. A large number of residents

and fire personnel sheltered in and around CFA sheds. In some cases, people sheltered in sheds, bunkers or open spaces such as sports ovals or paddocks; alternatively, they found protection in pools, dams or rivers.

- Some people believed bathrooms to be the safest room in which to shelter. Indeed, it was the most used room by people sheltering inside houses (58 people out of 246 with known location sheltered inside bathroom). The results showed that 37% of people sheltered in a room with poor visibility for active monitoring of the fire and poor exit options (mainly bathrooms and under the house). The perceived safety of the bathroom appears to stem from the ready availability or water and the contained nature of the room. It is noteworthy that children and pets were often confined to bathrooms, with and without the presence of adults.
- The research identified a number of so-called 'safe houses' that residents had planned to shelter in during a bushfire. Other residents had identified informal 'community refuges' where they believed they could shelter safely, including open areas such as sports grounds and local hotels and pubs.
- Due to the severity of the 2009 bushfires, some shelters failed and people had to seek alternative shelter. Some residents used multiple shelters, to a maximum of three shelter locations. A summary of these data showed that 84% of people survived in their first location of sheltering. Subsequently, of the 12% of people who moved to a second location, 87% survived. Finally, 2% of people moved to a third location where all of them survived.
- Most residents actively monitored the fire outside, as well as potential ignitions on and inside the house or building. Most actively protected the shelter by extinguishing ignitions, and protected occupants from smoke. It was common for some members of the household to shelter inactively, particularly children and the elderly; however, they were almost always protected by other members of the household who were actively defending or sheltering. There were only 22 cases out of 325 incidents in the witness statements and interviews where all members of the household sheltered inactively. In total, 53% (*n*=534) of the sample were active, 27% (*n*=273) inactive and 20% (*n*=200) were not known.
- Statistical analysis of the data showed that the number of people actively sheltering had the strongest influence on the probability of surviving in a sheltering location. This factor stood out above all others, including obvious factors like forest proximity and shelter status, in determining probability of survival.
- A number of challenges were consistently identified such as noise, air quality, falling objects, burning elements and a lack of visibility while sheltering, going to a place of shelter or exiting a shelter. Residents also described the challenges associated with exiting a burning house and finding a subsequent safe place to shelter. Finally, some people were challenged by the presence of children; the elderly; and disabled, ill, injured and stressed persons and the need to look after those people.
- One of the main challenges with sheltering within a house was the complexity in monitoring different occupiable and non-occupiable compartments (some house compartments, for example, in a roof or underfloor, are more difficult or impossible to monitor). Having multiple exit options appeared to be important for improving the likelihood of safe egress. Other challenges were the ability to recognise house ignitions and the circumstances where these ignitions developed beyond the capability of the occupants to suppress them.
- A large number of people experienced structural failure of their shelter. They faced major challenges and issues, 116 persons died inside of structures (including houses and other structures) and 160 (out of 838 persons) exited a burning house and found a second, and sometimes a third, place of shelter.

- The data identified that 59% of fatalities were in sheltering locations within 5 m of forest, and 90% within 35 m. Conversely, 50% of survivals were in sheltering locations within 15 m of forest, and 90% at 90 m.
- The research identified a number of beliefs about sheltering that may influence people's behaviour during bushfires.
    - While most people believed that houses are relatively safe places to shelter, others questioned whether houses could survive bushfires in extreme conditions, and therefore whether it was safe to shelter in them.
    - Some interviewees were considering building a 'bunker' or other structure in which they could shelter in future bushfires. Some people believed they could construct 'fireproof' structures that would guarantee their safety in a bushfire.

Key conclusions

- This research highlights that safe sheltering requires considerable planning and preparation by residents. It is important that residents shelter actively by continually monitoring conditions inside and outside the house, and by taking action to protect shelter occupants. This emphasises the relevance of active sheltering and the benefits of group dynamics in improving survival prospects.
- The findings of this work indicate that a shelter not only needs to be appropriately designed for the circumstances but also supported by well informed and capable shelterers. Information should emphasise that sheltering is not an alternative to leaving early or defending but may be necessary as part of a plan to defend or as a contingency plan when early evacuation is not possible.
- In many cases, wind was identified as a mechanism that compromised the structure of a building and made it more vulnerable to fire. This raised the question of whether current building design standards adequately address wind-related damage.
- People who were well prepared generally had better survival prospects than others. However, there were many examples in which well-prepared occupants were overwhelmed by the enormity of the defence task and the rate at which houses lost tenability. The question now remains whether building and planning regulations should more specifically target the circumstances leading to loss in these events. This can be specifically addressed by:
    - egress provisions in house and urban design
    - fragility of houses in extreme fire weather events with particular attention to wind effects
    - robustness principles on building design codes
    - role of heavy fuels in landscaping design to improve egress provisions
    - building regulations and design to provide confidence in the reliability of the building as a temporary shelter.

Executive summary iv

Part 1 Introduction, Literature review, Methods and data 1

1 Introduction 2

2 Literature review 4

2.1 Sheltering during other hazards 4

2.2 Bushfire sheltering policy and practice 5

2.2.1 Pre-1939 to 1983 period 5

2.2.2 1983 to 2009 period 6

2.2.3 2009 onwards 7

2.3 Planning and preparation 9

2.4 Resident decision making and response during bushfire 10

2.5 House vulnerability and factors influencing house survival 12

2.6 Summary of literature review 15

3 Methods and data 16

3.1 Data sources 16

3.1.1 Interviews with residents 16

3.1.2 Witness statements 17

3.1.3 Information on fatalities from the AGD Life Loss data base 17

3.1.4 Spatial data 17

3.2 Data collection 18

3.2.1 Sheltering data 18

3.2.2 Spatial information 19

3.3 Qualitative analysis 20

3.4 Quantitative and spatial analysis 20

3.5 Limitations and uncertainty in the data 21

Part 2 Result and discussion, and conclusion 22

4 Analysis of Black Saturday bushfires 23

5 Intention, planning and preparation for sheltering 25

5.1 Intention to shelter 25

5.1.1 Shelter as a primary strategy or first resort 25

5.1.2 Shelter as a backup or last resort 26

5.2 Planning and preparation for sheltering 27

5.2.1 Planning 27

5.2.2 House and building design 28

5.2.3 Preparation 28

5.3 Future plans for sheltering 30

5.4 Summary 32

6 Shelter type and beliefs about sheltering 33

6.1 Shelter type 33
6.1.1 Multiple shelter locations 34
6.1.2 Distance travelled between shelter 35
6.1.3 Sheltering inside a house (residential building) 38
6.1.4 Shelter in other structures around a residence 39
6.1.5 Vehicles 40
6.1.6 Water bodies 41
6.1.7 Open space and open space behind physical barrier 41
6.2 Safe houses and community refuges 44
6.3 Beliefs about sheltering 47
6.3.1 Safety of houses 47
6.3.2 Safety of bathrooms 48
6.4 Summary 49

7 Activity and challenges during sheltering 50

7.1 Factors leading to sheltering or not 50
7.2 Activity during sheltering 52
7.2.1 Active versus inactive sheltering 52
7.2.2 Monitoring 54
7.2.3 Actions to protect shelter and occupants 55
7.2.4 Group shelter 58
7.3 Challenges experienced while sheltering 59
7.3.1 Lack of visibility 59
7.3.2 Noises 62
7.3.3 Combustible elements 62
7.4 Health issues while sheltering 64
7.5 Summary 66

8 Failure of shelters 67

8.1 Structural failure experiences 67
8.1.1 Experiences of house failure 67
8.1.2 Wind damage to shelter before fire front arrival 70
8.1.3 Tenability of shelter 71
8.2 Spatial analysis 74
8.2.1 Fire severity and distance to forest 74
8.3 Statistical analysis of shelter location data 75
8.4 Summary 76

9 Policy implications and conclusion 77

10 References 81

11 Appendix 1: Coding framework 86

12 Appendix 2 Additional accounts 88

13 Appendix 3 Statistical analysis 90

Part 1 Introduction, Literature review, Methods and data

1 Introduction

This project, funded by the Australian Government under the Natural Disaster Resilience Grants Scheme (NDGRS[1]), aimed to examine the circumstances and challenges experienced when sheltering and/or exiting houses, sheds and personal bunkers during the 2009 Black Saturday bushfires. The analysis included human behaviour and decision making and also consideration of house design, fire behaviour and the surrounding landscape.

In Australia, fire agencies have historically encouraged a 'shared responsibility' approach with the objective of developing a range of risk mitigation measures (including self-protection measures) to protect life and assets. During a bushfire, all efforts are made to protect the community and houses, but in the case of major fires, it is not feasible for fire services to attend all properties. Hence, people should be prepared to protect themselves and their assets.

The main regulatory mitigation measures ahead of the fire season are fuel reduction (to reduce the hazard), and building and planning regulations to reduce vulnerability of houses to bushfire under different weather conditions. Those measures have two objectives. The main objective is to ensure that the house has an improved likelihood of resisting ignition from the fire; the other is to increase the chance of property survival.

Up until 2009, Australian fire services endorsed the 'Prepare, stay and defend or leave early' policy (Australasian Fire Authorities Council 2005[2]). Residents were advised to prepare to stay and defend their homes against bushfire, or leave before a fire threatened. The policy, which became known as 'stay or go', was criticised following the high death toll on Black Saturday – many people perished while sheltering in houses and other structures (Blanchi et al., 2014). It was argued that the dangers of staying to defend and the safer option of leaving early had not been adequately communicated to or understood by the public. Following recommendations made during the 2009 Victorian Bushfires Royal Commission (VBRC) (Teague et al., 2010) the policy is now known as 'Prepare. Act. Survive.' with a greater emphasis on leaving early as the safest response. Research has demonstrated that community response to bushfire risk is extremely complex and people often embrace a hierarchy of strategies in term of preparedness, response and decision making. These depend on the fire intensity, people's perceptions of the risk, and their individual circumstances (Handmer & Tibbits, 2005; McCaffrey et al., 2009; McLennan et al., 2012; Penman et al., 2013; e.g. Tibbits et al., 2008; Whittaker et al., 2013). For example, people might have intended to stay and defend or leave early but had additional priorities on the day or a lack of information about the fire and weather conditions. This could result in more risky behaviours such as leaving late or taking shelter within an ill-prepared house or refuge (Whittaker et al., 2013).

Studies of Australian fatalities over the last century have shown that 59% (Blanchi et al., 2012) to 78% (Tibbits et al., 2008) of all deaths occurred in the open space while leaving early or defending a property. However, recent studies found an increase in the number of fatalities where people sheltered inside a structure, rising from 6% for the 1901–1965 time period (Blanchi et al., 2012) to 40% for the 1965–2011 time period.

It is recognised that people might shelter by choice or might be caught unaware and have to find a shelter. Sheltering in a house or using another type of shelter (community or personal shelter) is still considered a potential option for community safety (Teague et al., 2010). However, several questions remain regarding the safety of sheltering under different weather conditions, the adequacy of people's preparation and behaviour, the adequacy of shelters to withstand the bushfire and the challenges people face when trying to shelter.

[1] https://www.emv.vic.gov.au/our-work/current-projects/natural-disaster-resilience-grants-scheme/ (accessed October 2015)
[2] AFAC (2005) Position Paper on Bushfires and Community Safety. AFAC Limited, Victoria, Australia (http://38c69b050a3d5d1eb1e3-aa923a4231e15c57e2802c896554e8a6.r6.cf4.rackcdn.com/D/D565388D-165C-412B-819C-F367B218C2D7.pdf (accessed October 2015)

Thus, much can be gained from a better understanding of appropriate resident sheltering and egress experiences in combination with a better understanding of how house design and fire severity influence the modes and rates of loss of house tenability.

This report is comprised of two parts. Part 1 presents a review of published literature on human behaviour, decision making, house vulnerability and other factors influencing house survival, and their implications for sheltering practices during bushfires. Part 1 also explains the methods used for the qualitative and quantitative analyses. Different sources of data were used to assemble the dataset including witness statements presented at the VBRC, semi-structured interviews conducted with residents in affected areas (Whittaker et al., 2009) and other available information from books, reports, journals and personal accounts that are publicly available. In addition, other circumstances were also included such as distance to vegetation, fire severity, building design and shelter status. Part 2 describes the results of the qualitative and quantitative analyses of the civilian fatalities and survivors of the 7 February 2009 'Black Saturday' Victorian bushfires in order to better understand the challenges faced by residents while sheltering. It focuses on the intention, preparation and planning for sheltering, the type of shelter used and belief about sheltering, the activity and challenges experienced during sheltering and discusses the issues related to shelter failure.

2 Literature review

The scope of this literature review is on the findings of bushfire research in relation to community bushfire safety and sheltering practices. We review the policy context in relation to sheltering, and discuss residents' planning and preparation, decision making, responses and house vulnerability.

The review briefly describes sheltering during other hazards but is mainly focused on Australian research due to Australia's unique approach to community bushfire safety and sheltering. In Australia, prior to each bushfire season, residents are given the option to decide whether they will stay and defend their house or property or leave before they are threatened by fire. The global context of community safety is also briefly discussed to contextualise the Australian approach.

The review covers the findings of published research including journal papers, reports on bushfire studies, VBRC reports and post-bushfire inquiries.

2.1 Sheltering during other hazards

Haynes et al. (2009) conducted a literature review of sheltering practices for a range of hazards and provided a detailed examination of sheltering as an option during flash flooding. They identified that although evacuation remains the dominant management strategy, there was growing awareness and some limited consideration of shelter-in-place in some circumstances. In particular, research shows that in addition to bushfires, sheltering and vertical evacuations during flash floods, cyclones, and radioactive and chemical emergencies may be safer than late evacuations (Haynes et al., 2009; Scanlon, 1992; Yard, 2000). The reasons cited include an inability in some circumstances to provide early warnings, land use planning and development that is not conducive to swift egress, and the dangers associated with mass evacuations other than encountering the hazard itself, such as accidents and traffic jams. For example, during Hurricane Rita in September 2005, 90 people perished due to the evacuation that occurred during a period of extremely hot weather compared to only three deaths attributed to the hurricane itself (Zachria et al., 2006). There is also evidence that those who shelter safely at home usually fare better emotionally during the post-disaster recovery process than those who leave, no matter what the devastation(Scanlon, 1997).

Although the likely benefits in some situations are clear, there remains limited understanding of people's sheltering awareness, plans and likely behaviours across these hazards (Haynes et al., 2009; Shepherd et al., 1998). In the Australian context, other than for bushfires, the exception is policy for sheltering in cyclones Following the devastation of Cyclone Tracy in the Northern Territory in 1974, building code reform has made it safer for people to shelter at home (Mason et al., 2013). For example, the Queensland government has developed comprehensive sheltering arrangements for cyclones and storm tides. A recent review of these arrangements (Inspector General Emergency Mamagement, 2015) found that the increased modern housing stock means that more people are able to shelter in their own houses, provided they are out of the surge zone, thereby reducing the burden on local government to provide cyclone shelters and places of refuge. It noted that although local governments were generally satisfied with their communities' levels of preparedness, the lack of consistent risk modelling across all coastal local government areas made it difficult to predict public shelter demand. The review concluded that 'Better information is required before we can be sure that Queensland's sheltering arrangements match the risks faced by the community' (p. 8). In terms of flash flooding in Australia, Haynes et al. (2009) concluded that sheltering-in-place must be better planned for in order to ensure it is a viable and safe choice when last minute evacuations are not feasible. In particular, this should include advice around how and where to shelter safely, the suitability of certain buildings and building codes, and the conditions likely to be experienced by those sheltering. However, Haynes et al. (2009) also warned against the dangers of using a shelter-in-place strategy as a justification for further building in hazard prone environments.

2.2 Bushfire sheltering policy and practice

The decision of whether to leave, stay and defend and/or shelter during a bushfire has always been a dilemma for residents and organisations in charge of issuing community advice and warnings. The outcomes of several studies show that there are no simple answers to this problem (Cova et al., 2009; Handmer & Tibbits, 2005; Haynes et al., 2009, 2010; McCaffrey et al., 2009; Paveglio et al., 2010; Stephens et al., 2009; Tibbits et al., 2007, 2008; Whittaker et al., 2013).

Early evacuation has been the preferred option in the United States (US) and in some countries in Europe, but this action is becoming more and more challenging, and alternatives to evacuation are now being widely considered (Cova et al., 2009; McCaffrey et al., 2009; Paveglio et al., 2008). Mass evacuation is complex and is not always feasible or safe due to population growth and at-risk assets (McCaffrey et al., 2009). Large-scale evacuation carries inherent risks and challenges for fire authorities. These risks are associated with accessibility, the ability to provide timely warnings, and the feasibility of evacuating people to a place of relative safety (Cova et al., 2009; Paveglio et al., 2008). This could lead to late evacuation, which has been recognised as the most dangerous response to wildfire/forest fire (Mutch et al., 2011; Xanthopoulos et al., 2009). There is also a change in people's attitudes, and growing evidence that people are reluctant to evacuate and are considering alternative approaches, such as staying and sheltering (Cova et al., 2009; Gill et al., 2009; McCaffrey et al., 2009; Moritz et al., 2014; Paveglio et al., 2008). In the US and in Europe, the notion of sheltering is mainly described as a backup option when evacuation cannot be performed. Cova et al. (2009) refers to 'sheltering-in-place' as taking refuge in a 'structure, safe area, or water body that offers a degree of protection from the direct effects of the fire'.

This section gives a brief presentation of sheltering practices during bushfires throughout Australian history and the evolution of the recommendations, policies and guidelines in relation to bushfire community safety in Australia, with a focus on Victoria.

2.2.1 PRE-1939 TO 1983 PERIOD

In Australia, the practice of sheltering during bushfires is not a recent phenomenon and has been practised in rural areas since European settlement (Handmer & Tibbets, 2005). Many of the official testimonials from people working or living in the bush come from the Black Friday bushfires in 1939 when people retreated inside structures such as a house, timber mill or dugout. While some found a refuge to hide from radiant heat and flames, others took shelter and actively defended (Brennan, 1979). In a quote below, Rose Le Brun, the wife of a mill worker, describes taking refuge in a powerhouse during the Black Friday bushfires:

> *And we got into the powerhouse which was a big galvanized iron building. And it had big wire doors, and we got inside and the kiddies, the 10 of us I think it was, we got into the battery room and stayed there. And the few men that were still about, they got out the wire doors that were about 10 feet high, and they held blankets up against the doors. Two of them were standing on a table holding blankets up against the wire door and two more were under the table holding blankets against the doors. And then two more men were holding them because of the force of the wind.*[3] (Rose Le Brun, wife of Ernie Le Brun, the Bush Boss at Skinner's Mill at Royston)

Drawing from earlier recommendations following the 1926 fires that killed 60 people, and a fire in 1932 that took nine lives, the Royal Commission into the 1939 fires advised for the construction of dugouts at vulnerable mill sites (Stretton, 1939).

> *Recommendations in 1932:*
>
> *All saw millers to construct effective dugouts in close vicinity of all sawmills, particulars of such to be forwarded to commission. 14 Nov. 1932* (Stretton, 1939) p. 18.

[3] http://www.abc.net.au/blackfriday/oral/oral_rose_lebrun.htm (accessed October 2015)

These recommendations are again included and emphasised in the 1939 report:

> *Safety precautions at sawmills must be improved:*
>
> *The construction of dug-outs at all mill settlements, and at winches during the fire season, should be compulsory.*

Issues that seem to have impeded the realisation of dugouts was the financial burden of the construction that would have been at the miller's expense and the fear of liability if people were to become asphyxiated in them (Stretton, 1939).

As described by Handmer and Tibbits (2005), following the 1939 fires an increasing number of studies and reports documented that remaining in the house, if appropriately prepared, was safer than last minute evacuations (Barrow, 1945; Luke, 1961). This also included investigations of life and house loss following the 1967 Hobart fires in Tasmania (e.g. McArthur & Cheney, 1967; Luke McArthur, A.G., 1978). However, the bulk of the research and public awareness came following the 1983 Ash Wednesday bushfires, which reinforced the idea that late evacuation was dangerous and that sheltering in prepared houses may save lives (Lazarus et al., 1984; Miller et al., 1984; Wilson et al., 1984). In particular, the post-fire investigation by Wilson and Ferguson (1984) revealed that house survival rates were 90% when the house was occupied by an able-bodied person.

The Bushfire Review Committee stressed the need to consider sheltering as a viable alternative to evacuation (Miller et al., 1984):

> *During the Ash Wednesday fires, a considerable number of people found communal shelter in large, well-constructed buildings and survived, even though the fire threat outside the buildings was acute.* (Miller et al. 1984, p. 162)

The recommendations noted that the State Government should provide or adapt school buildings in order that they could be used for shelters and reduce the need for students to evacuate:

> *Suitability of school buildings for use as shelters, particularly to mitigate the possibility of students being exposed to risk by being sent home ahead of an advancing fire front.* (Miller et al. 1984, p. 162)

2.2.2 1983 TO 2009 PERIOD

Policy

Following the Ash Wednesday fires, the message that a well prepared house offers better protection than late evacuation was becoming widespread (Handmer & Tibbets, 2005). However, the death of three people passively sheltering in a garage during the 1997 Dandenong Ranges bushfire highlighted the dangers of passively sheltering and the need to be proactive (Handmer & Tibbets, 2005).

Fire authorities officially moved away from the evacuation approach towards one where greater community self-reliance was encouraged. The 'Prepare, Stay and Defend or Leave Early' position was released by the Australasian Fire Authority Council (2005[2]). On page 5 of the document it states: 'People need to prepare, then stay and defend their property, or leave early.'

This 'Prepare, Stay and Defend or Leave Early' policy states that 'People need to prepare their properties so that they can be defended when bushfire threatens. They need to plan to stay and defend them, or plan to leave early' (AFAC 2005[2]). The policy is based on the cumulative findings of several studies, many of which are discussed above, that demonstrate that people sheltering in their house and actively implementing different protection strategies have a better chance of survival than people evacuating late (Krusel et al., 1999; Lazarus et al., 1984; McArthur et al., 1967; Wilson et al., 1984). The lessons learnt from post-bushfire surveys identify late evacuation as the most dangerous option in Australia (Handmer & Tibbets, 2005; Handmer & Tibbits, 2005; Haynes et al., 2010; Krusel et al., 1999; McArthur et al., 1967; Tibbits et al., 2007). In addition, studies also show that a well prepared house and active defence by able-bodied

residents or brigade members significantly increases the chances of house survival (Barrow, 1945; Blanchi et al., 2008; Ramsay McArthur, N.A. Dowling, V.P., 1987).

The policy, which colloquially became referred to as the 'stay or go' policy, essentially remained unchanged until Black Saturday. This was despite knowledge among the fire authorities and researchers that the message was not clearly applicable to all circumstances and carried inherent risks when the fire behaviour exceeded the expectations and capabilities of residents (Tibbits et al., 2007, 2008).

Practice

In 1996, the fire authorities and emergency services started to develop guidelines that addressed refuge possibilities other than houses. The Country Fire Authority (CFA) describes in its Bushfire Survival Plan Workbook (1996) two different sheltering options:

> *There are various survival options for you to choose from:*
>
> - *Go to a designated refuge area*
> - *Go to a neighbour's home*[4]

The Bushfire Survival Plan Workbook published in 2004 does not mention a designated refuge area and the only option given, aside from staying and defending, is to find refuge at a neighbour's house.[5] However, in an 'Advice To Community Before And During Wildfires 2006. A guide for CFA personnel', the authority reintroduces the sheltering strategy and asserts:

> *CFA personnel should advise residents not to get caught in the open by seeking temporary shelter … that may be found inside the home or structures such as neighbouring houses, Fire Refuges or in municipal assembly areas.*[6]

'Living in the Bush' 2008 states that options include sheltering in a neighbour's house or finding refuge in an emergency relief centre:

> *If your plan includes going to a neighbour's house or an emergency relief centre, you would need to do this well before the arrival of the main fire front.*[7]

2.2.3 2009 ONWARDS

Following the high death toll on Black Saturday, in particular the large numbers of people who died while sheltering, the policy was scrutinised and reviewed by the VBRC (Teague et al., 2010). It was believed that the dangers of staying to defend and the safer option of early evacuation had been overlooked by the policy and therefore not adequately communicated or understood by the public. The VBRC recommended that early evacuation is the safest response. However, it recognised that timely evacuation is not always possible or achievable and contingency planning is needed through a broad range of strategies rather than the binary approach of staying or leaving (Teague et al., 2010).

Since the 2009 bushfires, the position on bushfires and community safety has changed, and greater emphasis is now placed on human safety with a focus on early evacuation as the safest response. Bushfire safety depends on people having access to a range of safety options. All options other than being out of the fire area involve varying degrees of danger. Bushfire safety involves effective planning and preparation prior to a fire, making informed decisions during the event, and having access to a range of safety options, in particular places to shelter from the effects of the fire. [8]

---

[4] Living in the Bush. Bushfire Survival Plan Workbook. 1996 p. 1
[5] Living in the Bush. Bushfire Survival Plan Workbook 2004 p. 9
[6] Advice to community before and during the wildfire. A guide for CFA personnel
[7] Living in the bush. Bushfire Survival Plan Workbook 2008 p. 10
[8] http://fire-com-live-wp.s3.amazonaws.com/wp-content/uploads/2013-Bushfire-Safety-Policy-Framework.pdf (accessed October 2015)

Following the recommendations of the VBRC (Teague et al., 2010) a new set of bushfire safety principles were implemented by all Australian fire services[9] with the 'Prepare. Act. Survive.' message. The message highlights the importance of preparation well ahead of the fire, the need to take action on the forecast daily fire danger rating, and to recognise when a resident might be caught in an unexpected situation and need to shelter-in-place during the bushfire. This last point stresses the importance of contingency planning and alternative options if the fire or personal circumstances prevent planned preparations and actions.

Since the 2009 fires, additional strategies have been proposed such as Community Fire Refuges and Neighbourhood Safer Places in Victoria, Bushfire Safer Places in South Australia, personal fire bunkers, and last resort refuges (sports ovals and water bodies). These assist people by providing a range of contingency plans when their primary plans are not viable. Several documents have been produced to help design and use those strategies, for example, the Australian Building Code Board has produced a document to assess the performance of private bushfire shelters[10] and some fire services are helping municipalities to design Neighbourhood Safer Places and provide information to communities. [11] However, these strategies have some limitations and challenges. There is inherent risk with evacuation to a shelter in terms of managing the risk exposure while attempting to access the shelter (Leonard, Blanchi, Leicester, Lipkin, Newnham, et al., 2009).

The implementation of different strategies should consider different fire weather conditions and adequate backup options. Some of the changes introduced by the Victoria Planning Provisions on 31 July 2014[12] (amendment VC109) have implications on the relationship between life and property safety with the allowance for reduced construction requirements of a building if an accredited private bushfire shelter is installed.

Guidelines published by the CFA now have an entire section termed 'plan for survival' that clarify the practice of sheltering. The 2011 and the 2013 'Fire Ready Kits' address the different sheltering options and make the distinction between all types of shelter, define what a 'Neighbourhood Safer Place' is and, more importantly, what it is not. The 'Neighbourhood Safer Place Assessment Guidelines' developed by the CFA is also available online. It describes, in detail, what to expect from this type of refuge.[13] Importantly, the shelter is described as a place where people need to be vigilant and remain active.

> *For your safety, you need to be active while sheltering. Know if you need to move to a safer position. If you are not able to see what is going on, you are placing yourself in a potentially life-threatening situation.*[14]

It also specifies that these places do not guarantee safety and that there is a high risk of trauma, injury or death, the very reason they are options of last resort.

In the long-standing Australian relationship with bushfires, sheltering holds a substantial place in survival chronicles. However, emergency management during bushfires has remained a complex endeavour, oscillating between priorities given to the 'leave early' strategy or the defence of a property. Both strategies have revealed shortcomings that had detrimental and fatal consequences on individuals and communities, particularly after Black Saturday. Drawing on survival stories from Black Saturday, the VBRC states that for many people who lacked a well-thought plan and were left to make their own decision 'the provision of shelter, or refuge or evacuation, became critical' (Teague et al., 2010).

---

[9] For example http://www.rfs.nsw.gov.au/__data/assets/pdf_file/0017/2933/BushFireSurvivalPlan.pdf; http://www.cfa.vic.gov.au/plan-prepare/fire-ready-kit/; http://areyouready.wa.gov.au/documents/DFES_Bushfire-Prepare_Act_Survive_Guide.pdf; https://ruralfire.qld.gov.au/Fire_Safety_and_You/Prepare.Act.Survive/; http://www.fire.tas.gov.au/Show?pageId=tfsDVDDownloads; http://www.cfs.sa.gov.au/site/prepare_for_bushfire.jsp (accessed October 2015)

[10] http://www.abcb.gov.au/en/education-events-resources/publications/ABCB%20Performance%20Standards.aspx (accessed October 2015)

[11] For example http://www.saferplaces.cfa.vic.gov.au/cfa/search/default.htm (accessed October 2015)

[12] http://www.dtpli.vic.gov.au/__data/assets/pdf_file/0007/230497/Practical-Reforms-for-Building-in-Bushfire-Designated-Areas-Info-Sheet.pdf (accessed October 2015)

[13] http://www.cfa.vic.gov.au/fm_files/attachments/plan_and_prepare/nsp-assessment-guidelines.pdf (accessed October 2015).

[14] Prepare Act Survive. Fire Ready Kit 2011.

2.3 Planning and preparation

Regardless of whether they intend to stay or leave, residents are encouraged to undertake preparations to increase the likelihood that their house and other property will survive.[4] Preparation is particularly important in the event that residents who intend to leave are prevented from doing so. Research on resident planning and preparation identifies a number of factors and circumstances that may increase the risk that residents will need to take shelter during a bushfire.

Inadequate planning and preparation

A number of studies highlight the varied levels of planning and preparation among residents in high bushfire risk areas (e.g. McGee & Russell, 2003; Whittaker et al., 2009; Prior, 2010). Research suggests that residents are more likely to undertake 'easy to do' preparations, such as clearing vegetation from around the house, and are less likely to engage in more difficult or complex tasks such as protecting vulnerable points on houses or developing detailed bushfire survival plans (Rhodes, 2011; Whittaker et al., 2013). A number of studies find that while residents may be aware of the risk and consider themselves well informed and prepared, most overestimate the effectiveness of their level of planning and preparedness (Bushnell et al., 2007; Rhodes, 2011; Whittaker et al., 2013).

Research undertaken following the 2009 fires identified shortcomings in many residents' preparations that compromised their ability to enact their plan (McLennan et al., 2013; Whittaker et al., 2009, 2013, 2015). Many residents had not considered what they would do if equipment failed, if other household members were not home, or if they were overwhelmed by the fire. The lack of 'backup' plans was particularly evident in situations where residents intended to leave early but stayed because it was too dangerous to leave, or intended to defend but abandoned their house because of the intensity of the fire or because defence was unsuccessful (Whittaker et al., 2009). In circumstances such as these, taking shelter may be the only option for residents. McLennan et al. (2013) argue that educational material about property defence should emphasise the risks involved and the need for a sound backup plan in case defence fails. A sound backup plan is also necessary for those who intend to leave.

The critical role of planning and preparedness in bushfire safety has been highlighted by studies of civilian fatalities in the 2009 fires (Blanchi et al., 2012; Handmer et al., 2010). Results of a study of preparedness, intentions and actions related to civilian fatalities in the 2009 Victorian bushfires (Blanchi et al., 2012) found that most people who died within a structure had a plan or intention for how they would respond to a fire (for example, 40% had intended to stay and defend, 23% had planned to leave when threatened and 16% did not have a plan or the plan was unclear). These results stress again the importance of contingency plans.

'Wait and see' strategies

A number of studies have identified the tendency for residents to wait until they are directly threatened by fire before deciding whether to stay or leave (McLennan et al., 2013; Rhodes, 2005; Tibbits et al., 2007; Whittaker & Handmer, 2010; Whittaker et al., 2013). A study by Rhodes (2005) found that while most residents believed that 'stay and defend' was a viable strategy for protecting property, most did not see it as a strategy for protecting life. Consequently, people prefer to 'wait and see' what a fire is like before they decide what to do, which may increase the potential for people to undertake late evacuations or become trapped at their house. Similarly, in a study of public understanding of the 'Stay or go' policy, Tibbits and Whittaker (2007) found considerable confusion over the meaning of 'leave early'. Many of those who intended to leave were unsure of when to go, while many of those who planned to stay and defend were not fully committed to doing so. A study of household preparedness and responses to the Black Saturday bushfires found that around one-quarter (26%) of residents had intended to 'wait and see' (Whittaker et al., 2013). The authors argue that residents who wait until the last moment before taking action are more likely to end up in dangerous situations including late evacuation and active or inactive sheltering in an unsafe structure.

2.4 Resident decision making and response during bushfire

In the 2009 Black Saturday bushfires, 118 people died inside houses or other structures. However, analysis by Blanchi et al. (2012) identified only six instances where occupants had planned to shelter inactively. This suggests that a large number of those who died inside found themselves in situations they had not planned for. Preliminary analysis of the circumstances surrounding these fatalities reveals that although many died sheltering, levels of preparation and actions prior to death varied significantly (Blanchi et al., 2012). This highlights that knowledge, pre-planning and decision making are critical to facilitate safe bushfire responses, including sheltering practices.

Whittaker et al. (2013) studied residents' intended and actual responses to the 2009 Black Saturday bushfires through a mixed methods approach involving 611 in-depth interviews and a quantitative survey with 1314 households. Intended responses were influenced by a broad range of factors including age; physical capacity, mobility and health; responsibility for children, the elderly and others requiring assistance; responsibility for pets and livestock; the location of the property; perceptions of preparedness and capacities to defend; and the presence or absence of other household members during a fire. Of 1314 respondents, half reported that they had intended to stay and defend throughout the fire (50%), while one-fifth (21%) had intended to leave before they were threatened by fire (see Table 1). As noted in the preceding section, one-quarter (26%) had intended to wait until the fire arrived before deciding what to do.

Table 1 Intended versus actual responses to the 2009 Black Saturday bushfires (from Whittaker et al., 2013).

Intended response	Actual response
Stay and defend (*n*=565)	Stayed and actively defended (72%) Left before the fire arrived (9%) Left when the fire arrived (7%) Began defending but left (9%) Took shelter (3%)
Stay and defend but leave if threatened (*n*=191)	Stayed and actively defended (17%) Left before the fire arrived (26%) Left when the fire arrived (33%) Began defending but left (20%) Took shelter (5%)
Wait and see (*n*=102)	Stayed and actively defended (16%) Left before the fire arrived (18%) Left when the fire arrived (41%) Began defending but left (22%) Took shelter (4%)
Wait for advice (*n*=23)	Stayed and actively defended (26%) Left before the fire arrived (17%) Left when the fire arrived (48%) Began defending but left (4%) Took shelter (4%)
Leave when there is a fire (*n*=195)	Stayed and actively defended (2%) Left before the fire arrived (48%) Left when the fire arrived (43%) Began defending but left (2%) Took shelter (6%)
Leave when high fire danger (*n*=21)	Stayed and actively defended (0%) Left before the fire arrived (90%) Left when the fire arrived (10%) Began defending but left (0%) Took shelter (0%)
No intended response (*n*=12)	Stayed and actively defended (50%) Left before the fire arrived (17%) Left when the fire arrived (17%) Began defending but left (8%) Took shelter (8%)

Table 1 highlights significant differences between intended and actual responses to the 2009 fires. Those who intended to stay and defend were more likely to follow through with their plan, as were those who intended to leave on all days of high fire danger. Those with less firm plans – such as those who intended to stay and defend but leave if threatened, and those who intended to wait for advice or to see what the fire was like – were more likely to leave once the fire had arrived. With the exception of those who intended to leave on days of high fire danger, between 3 and 8 percent of residents in each category of intended response eventually sheltered from the fire.[15] McLennan et al. (2012, 2013) reported similar proportions of residents sheltering during the Black Saturday bushfires.

The study by Whittaker et al. (2013) on resident responses to the fire showed that the majority of questionnaire respondents (53%, *n*=547 from a total of 1042) reported that they stayed to defend their houses and properties from the bushfires (Table 2). Almost half (44%) of these respondents left their houses or properties either before or when the fires arrived in their town or suburb. A small proportion (4%) reported that they sheltered inside a house, in a structure other than a house, in a vehicle, or

[15] Note that this study did not differentiate between 'active' and 'inactive' sheltering.

somewhere outside during the fire. One-third (33%, *n*=190) of respondents who stayed with their house or property reported leaving at some stage during the fire. One-quarter of these respondents (25%, *n*=48) reported leaving because utilities or equipment failed and/or because their house caught fire (15%, *n*=29).

Table 2 Resident responses to the Black Saturday bushfires (Taken from Whittaker et al., 2009, p. 27).

Response	Frequency	Percent
Left before the fire arrived in my town or suburb	235	21.3
Left when the fire arrived in my town or suburb	219	19.8
Stayed and actively defended the house and property	419	38.0
Began defending the house and property from the fire but left when I felt the danger was too great	109	9.9
Stayed to actively defend the house or property but the fire never arrived	19	1.7
Did not actively defend the house and property but stayed throughout the fire and sheltered inside the house	16	1.4
Did not actively defend the house or property but stayed throughout the fire and sheltered in a structure (other than the house) or vehicle	11	1
Did not actively defend the house or property but stayed throughout the fire and took refuge somewhere outside	14	1.3
SUBTOTAL	1042	94.4
Missing data	62	5.6
TOTAL	1104	100

Qualitative interviews with 600 households affected by the Black Saturday bushfires provide insight into community members' sheltering practices (Whittaker et al., 2009). The study found that many community members sought shelter in public buildings, sports ovals and emergency services facilities because they believed them to be safe places of refuge during a bushfire. Others took shelter in houses, cellars, concrete water tanks, swimming pools, dams and other structures. Some residents had plans to build personal bushfire shelters or 'bunkers' to protect them from bushfires. The study also reported anecdotal evidence that many of those who sheltered passively inside their houses sought refuge in bathrooms (Whittaker et al., 2009). Further analysis of the 600 interviews has been undertaken as part of this project.

McLennan (2010) studied informal places of shelter and last resort used during the 2009 Victorian bushfires with a particular focus on community places of shelter such as Gallipoli Park oval, in Marysville, and CFA fire station sheds. The study demonstrates that many people (including civilians and emergency service personal) survived by sheltering in their vehicles on large cleared areas or inside buildings (sheds). Overall the authors mention that very few of the civilians who sought refuge were prepared to take shelter and some end up there because they did not have any other safer alternatives (McLennan, 2010).

2.5 House vulnerability and factors influencing house survival

Staying and defending a house implies that the house can maintain its integrity and protect the occupants from the effects of the fire (mainly flame, radiant heat and smoke) during the passage of the fire front. From a building perspective, there are several issues that might contribute towards the failure of a house to protect people, including:

- the timing of house ignition in relation to the passing of the fire front
- the location of the ignition(s) within the building and the ease to extinguish
- the rate in which the original ignitions develop to threaten the tenability of the building
- the available egress paths in the final stages of tenability loss.

House design, maintenance and landscape all contribute to the above factors and should be carefully considered when developing a strategy for sheltering in a house.

House ignition context

Studies in Australia and the US identify the role of urban fuel combustion (e.g. adjacent structures, fences, stored material) as the predominant cause of house destruction (Barrow, 1945; Blanchi et al., 2008; Cohen, 2000; Leonard, 2003; Manzello et al., 2012; Ramsay McArthur, N.A. Dowling, V.P., 1987). House ignition may be caused by burning debris (embers) such as leaves, twigs and bark that travel from the main fire body to the building and surrounding elements before, during and after the fire front has passed. Consequently, most houses survive the passage of the fire front, but burn down in the following hours due to ember attack or attack by surrounding element that were ignited and are now burning in the vicinity of the house (Leonard et al., 2005).

If action is not taken to extinguish these small ignitions, they can grow to involve the whole building. When present, occupants play a primary role in maintaining house integrity during the passage of the fire front and also play an important role in house survival. Several studies show that active defence by residents, brigade members or both results in a three to seven times greater chance of the house surviving the fire (Leonard et al., 2005; Ramsay et al., 1986; Whittaker et al., 2013; Wilson et al., 1986).

Weather conditions also play an important role in house destruction. A study on house loss and environmental circumstances show that most of the losses occurred under catastrophic fire weather conditions (forest fire danger index above 100) (Blanchi et al., 2010). Similarly, a detailed study of the location of fatalities inside structures (Blanchi et al., 2012) shows that 28% of fatalities associated with past bushfires have occurred in houses. This percentage rises to 60% when bushfire impacts occur under catastrophic fire weather conditions (Blanchi et al., 2012).

Wind has also been identified as one of the mechanisms of attack during bushfire (Blanchi et al., 2011). There is substantial evidence from post-bushfire surveys of wind-related damage during bushfires (Leonard et al., 2005; Leonard, Blanchi, Leicester, Lipkin, Newnham, et al., 2009; Ramsay McArthur, N.A. Dowling, V.P., 1987). The wind can damage the integrity of a building, making it more prone to cavity ignitions that can develop undetected and subsequently hamper safe egress (Blanchi et al., 2011).

The mechanisms of house ignition are well known but are difficult to quantify. The complexity of urban design and its behaviour during bushfire attack make it difficult to assess the exposure and house response (Leonard, Blanchi, Leicester, Lipkin, & Black, 2009). The Australian Standards (AS3959-2009) propose a method to evaluate the radiation exposure level taking into account fire weather conditions, surrounding vegetation and slope (McArthur, 1967; Standards Australia, 2009). Some work has been done to improve this method and provide a detailed risk assessment and inventory of potential impacts on the house (Leonard, Blanchi, Leicester, Lipkin, & Black, 2009; Newnham et al., 2014; Siggins et al., 2013) but further research is needed to develop an effective risk framework.

Building and planning regulations

In response to bushfire threat, building and planning regulations have been in place in Australia to improve the resistance of buildings to the impact of the fire and their performance during the passage of the fire front. In terms of building regulations, most states and territories have adopted National Construction Code specification for bushfire construction. These consist of two separate standards: Australian Standard AS3959 'Building in bushfire prone area' (Standards Australia, 2009) and the National Association of Steel-Framed Housing (NASH) standard[16] with either minor or major variations. The AS3959 specifies the construction requirements for building construction in bushfire prone areas and defines a site assessment method for the predicted exposure levels of the house. The NASH standard relies on the site assessment method in AS3959 but specifies its own set of aims, objectives and construction requirements. Of particular interest is the fact that AS3959 focuses on reducing ignition risk using facade design details while NASH

[16] http://www.nash.asn.au/nash/home.html (accessed October 2015)

identifies both ignition and egress issues and addresses them by specifying non-combustible facade, cavity design and decking supports.

The Australian Standard AS3959 also acknowledges its limitations by mentioning that building survivability in bushfire is complex and is influenced by a number of different factors (not only construction requirements) (Standards Australia, 2009). There is uncertainty regarding the construction requirements to maintaining the house integrity in all fire weather conditions. When the fire weather exceeds the construction standard the house may no longer provide a safe place to shelter during the passage of the fire front.

Before the 2009 bushfires, fire services described the duration of exposure to the fire front of around 20 minutes. However, during the 2009 bushfires some residents experienced longer exposure durations and reported that the fire front passage lasted between 45 and 50 minutes (Leonard, Blanchi, Leicester, Lipkin, Newnham, et al., 2009; Teague et al., 2010). This was exacerbated by the severity of the weather conditions on the day, which could have easily jeopardised the integrity of the buildings (Leonard, Blanchi, Leicester, Lipkin, Newnham, et al., 2009).

There has not been a specific study on how a house built to a standard will perform without maintaining it to the standard at which it was built; however, it is likely that a number of additional ignition paths will develop over time if the occupant fails to understand the intent of the design measures and the need to maintain them accordingly. Another issue is the lack of statistical verification on the performance of compliant-to-regulation houses during a major bushfire.

Loss of tenability

Buildings are ignited either externally, within the building cavity, or by direct ignition of the building contents. Some ignitions, such as fire in an internal roof cavity, are less likely to be detected and defended by an occupant. The rate at which a house loses tenability is influenced by the type of ignition, the weather conditions, the construction style of the building, the extent to which it has been damaged by other actions (e.g. wind), how well the building has been prepared, the building's contents, and preparation activities undertaken by residents (Blanchi et al., 2008).

When a building begins to lose tenability, the people using it as a shelter need to be able to recognise when it is necessary to exit and move to a place of relative safety. It appears that many of the people whose lives' were lost, during the 2009 bushfire, did not attempt to exit as tenability was lost in the house (Blanchi et al., 2012). Recent outcomes from a Victoria Police report on fatalities during the 2009 bushfires emphasise this point and report that, without exception, residents would die if they could not exit a burning house (Hart, 2014). While this is an obvious conclusion, it does emphasise the point that no part of a house remains tenable throughout the process of it burning down. Previous studies of the 1983 Ash Wednesday fire in Victoria (Krusel et al., 1999) and the 1967 Hobart fire (McArthur et al., 1967) show that a small number of fatalities occurred inside houses, which predominantly involved occupants sheltering in rooms (e.g. bathroom) with no clear view of the evolving circumstances outside of the structure. Studies on fatalities while people sheltered in houses show that 41% occurred in rooms with reduced visibility to outside conditions (bathroom, enclosure, laundry, study, toilet block, bunker) (Blanchi et al., 2012). This means that residents were either not aware of the need to leave or were unwilling to do so, or the house lost tenability at a rate in which movement within the house was not possible following recognition the structure had caught fire. It is also reasonable to assume that in some cases it may have been unsafe both inside and outside the building concurrently (Blanchi et al., 2012).

Safe egress issues

Another point to consider is the ability to safely exit a building and travel over burnt ground to a place of safety (Blanchi et al., 2011). Egress is also important to consider when accessing a shelter. During the 2009 bushfires some residents experienced this challenge and reported difficulty exiting their house and travelling to an alternative shelter location (Blanchi et al., 2012). Gill and Stephens (2009) have also discussed the challenges in better understanding fire danger information to accurately estimated safe egress from a house.

If a house ignites, safe egress is dependent on the opportunity to move outside to a burnt out area before the house becomes untenable. Therefore, to maximise the chance of safe egress, the house should be designed to limit ignition, and if ignition occurs this ignition should be readily recognisable. There should also be multiple egress paths free of ignitable facades or decks to avoid entrapment. The egress path inside and outside the structure should not be hampered by combustible elements (e.g. vegetation, car, garden furniture, woodpile), or elements that lose structural integrity (e.g. timber decking) in a bushfire event (Blanchi et al., 2011). Building regulations unfortunately provide little guidance on how to design for egress (Blanchi et al., 2011).

2.6 Summary of literature review

Leaving early (or evacuation) is the preferred strategy for protecting human life in bushfires. However, it must be recognised that evacuation is not always possible and that alternatives are required. Research demonstrates that several strategies are needed to take into account the specificity of the risk and potential impact of fire under different weather conditions (Cova et al., 2009; McCaffrey et al., 2009; Paveglio et al., 2008). Those studies and the recommendations of the VBRC emphasise the need for a range of options and backup plans adapted to several situations.

Research on resident planning, preparation and response identifies a number of factors and circumstances that may increase the risk for residents to take shelter during a bushfire. Residents who wait until the last moment before taking action are more likely to be faced with multiple high risk options ranging from late evacuation to sheltering in a poorly prepared structure. Buildings and surroundings could be designed to sustain a certain fire exposure, based on fire weather conditions. However, variation and unpredictability in fire behaviour make it difficult to characterise the fire exposure and the vulnerability of the house. In addition, there is little research on the compatibility between people's behaviour and these measures or their efforts to prepare for and maintain house survivability.

Factors influencing safe sheltering need to be better understood in terms of preparedness, behaviour, types of shelter, exposure to fire and smoke and vulnerability of the shelter. While many studies have investigated evacuation and alternatives (such as staying to defend and inactive sheltering), few have considered 'active' or safe sheltering practices.

Fundamental questions remain regarding residents' knowledge and understanding of safe sheltering practices, structural failure mechanisms and the planning and preparation that is required to shelter safely.

3 Methods and data

The analyses focused on the sheltering experiences of the people affected by the 7 February 2009 Victorian bushfires. This fire event affected a large number of people and has a fairly comprehensive collection of data, interviews and supplementary information associated with it. The analyses aimed to answer the following questions: did people intent to prepare for sheltering? Where they shelter? What actions they took and what are the challenges and risk they faced while sheltering?

This section includes descriptions of the data sources, the processes employed to collect and aggregate the information on sheltering practices and the methods used to analyse the data. The methods involved two distinct qualitative and quantitative components. In addition, case studies were used to emphasis some of the residents' experiences. These are descriptive of a particular situation and can incorporate qualitative and quantitative methods.

3.1 Data sources

Different sources were used to collate information on fatalities and survivors affected by the 2009 Victorian bushfires:

- 611 semi-structured interviews with residents affected by the 2009 bushfires (Whittaker et al., 2009, 2013)
- witness statements and hearings transcripts available online from the VBRC report (Teague et al., 2010)[17]
- a dataset containing bushfire related life and house loss in Australia over the past 110 years (1901–2011) (Blanchi et al., 2012)
- other sources of information including journal papers, reports (e.g. Whittaker et al., 2009, 2010; Leonard et al. 2009a; O'Neill et al., 2010; Blanchi et al., 2012), books (e.g. Kissane, 2010; O'Connor, 2010; Stanley, 2013), publicly-available personal accounts[18], internet, newspaper articles (available on internet) and fire agency documents.
- spatial information (e.g. vegetation layer, fire severity, building surveys).

Only cases presenting information on sheltering were considered in the analysis.

3.1.1 INTERVIEWS WITH RESIDENTS

Immediately following the 2009 Black Saturday bushfires, the Bushfire CRC established the '2009 Victorian Bushfires Research Taskforce' to examine fire behaviour, human behaviour and community safety, and building and planning issues. The overall aim was to collect valuable data to inform the VBRC and Australian fire and emergency services. A mixed methods approach was utilised involving 611 in-depth semi-structured interviews with residents, at their homes, followed by a questionnaire sent via mail to a sample of residents in bushfires affected areas[19]. Only households in the fire impacted areas were targeted and due to the level of damage and displacement, a purposefully random technique could not be employed. Interviews were therefore conducted when and where residents were found to be home. However, the final sample covered a range of different locations and outcomes in terms of fire exposure and human

[17] http://www.royalcommission.vic.gov.au/Commission-Reports/Final-Report.html (accessed October 2015)
[18] http://blacksaturdayandbeyond.com.au (accessed October 2015)
[19] Surveys were mailed to 6000 addresses in areas affected by the bushfires in October 2009. Addresses that fell within the 'burnt area', as defined by DSE, were extracted from the Vicmap database (see http://services.land.vic.gov.au/landchannel/content/productCatalogue, accessed October 2015).

behaviour. Interview topics included preparations, information and warnings, intentions, actual responses and future plans. Interviews were digitally recorded with the permission of interviewees and later transcribed. For more information on the methods, please see Whittaker et al. (2013).

Initial analysis through word searches of the 611 (total) interviews revealed that 315 contained references to sheltering. These interviews were used for this research. A full description of the analysis process is detailed below in Section 3.3.

3.1.2 WITNESS STATEMENTS

All transcripts of evidence from lay witnesses[20] (100 witness statements) and hearings[21] presented to the VBRC were considered in this study together with any associated material such as photography or documentation provided by the witnesses (Teague et al., 2010). The term lay witness was used by the VBRC to describe people who were directly affected by the bushfires and who told their personal stories orally to the VBRC (but who did not represent a particular organisation). The commissioner stated in the introduction to the fourth volume of the report[22] that the lay witnesses were identified in various ways, including from community consultations in fire affected communities in March and April 2009, and written submissions to the VBRC. They represented a small proportion of the people affected by the fire and their submissions covered the residents' different experiences of the fire. In this report, we have used the term 'witness statement' to refer to these submissions. Half of the witness statements (50 cases) described sheltering practices and experiences during the fire and were included in this study.

3.1.3 INFORMATION ON FATALITIES FROM THE AGD LIFE LOSS DATA BASE

The Attorney General's Department (AGD) National Fire Danger Rating System Life Loss database is a spatial dataset of fatalities due to bushfires and related losses and circumstances (such as house loss, weather context, fire severity, and distance to forest) in Australia for the past 110 years (1901–2011) (Blanchi et al., 2012). The database contains information on location of fatalities, time and circumstances of death, activity prior to fatality (e.g. sheltering, defending, evacuating), and decision making. All available information relating to the fatalities that occurred during the 2009 Victorian bushfires was included in this analysis. In total, 169 deaths and 80 incidents and associated data were considered (the official fatality number is 173; however, three deaths that occurred on the day were not related to the effect of the fire and one death occurred after 7 February 2009 during the mopping up operation).

3.1.4 SPATIAL DATA

The National Carbon Accounting System (NCAS) forest non-forest (FNF) layer (Furby et al., 2009) was used to determine the distance to forest and percentage of forest within 100 m of each location. The forest analysis does not show of grass or short vegetation fuel (<2 m in height) or forests covering <0.2 ha. The Dynamic Land Cover Map (Lymburner et al., 2011) and the Ecological Vegetation Class (EVC) layer[23] were used to determine the type of vegetation at each location. A fire severity layer was produced for the Kilmore region (Cruz et al., 2012) and further vegetation characterisation was derived from the vegetation layer developed for this specific study.

Information on house locations and materials was obtained from the Bushfire CRC Research Taskforce 2009 bushfire survey (Leonard, Blanchi, Leicester, Lipkin, Newnham, et al., 2009). The datasets contain information on the building materials, construction and surrounding elements. However, houses or

[20] http://vol4.royalcommission.vic.gov.au/index82b9.html?pid=136 (accessed October 2015)
[21] http://www.royalcommission.vic.gov.au/Hearing-Schedule.html (accessed October 2015)
[22] http://vol4.royalcommission.vic.gov.au/intro.html (accessed October 2015)
[23] Department of Environment and Primary Industries Victoria (DEPI). Native Vegetation – Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS). Victoria
http://www.giconnections.vic.gov.au/content/vicgdd/record/ANZVI0803003495.htm (accessed October 2015)

properties where fatalities occurred were excluded from the data collection process due to legal and site access issues following the bushfire event. Most of the data on building construction and materials are related to houses of residents that survived the fire.

The house location data was extracted from the National Exposure Information System (NEXIS) database that was developed by Geoscience Australia (Nadimpalli et al., 2007). The database contains approximate position and number of dwellings based on the Geocoded National Address File (G-NAF). The G-NAF address system identifies the house by either its centroid or a point on the cadastral boundary close to its street access.

3.2 Data collection

For the quantitative analysis, information was collected at the incident level and at each spatial location of shelter(s) for each individual (if available). An incident can refer to one or several persons where individuals were sheltering or behaving as a collective group. It also refers to a household where, in some cases, some members of the household sheltered at different locations (for example, one member inside the house and another outside the house). Different types of variables were collected at the incident level including categorised variables (e.g. location of shelter) and quantitative variables (e.g. distance to forest). The data was extracted from the same sources as the qualitative analysis (semi-structured interviews and witness statements). In addition, information from other sources was recorded in the dataset. Some information was coded in order to facilitate the analysis. The coding system used in this project was developed by a three-member team. The system includes information on people, shelters and activities (see Appendix 1). Further, information was also extracted from the spatial data sources described above.

A spatial database was developed on civilian sheltering practices for the quantitative analysis. This dataset includes tabular data stored in a Microsoft Access database and associated spatial data stored in ArcGIS. The data are described in Sections 3.2.1 and 3.2.2 and in Appendix 1. The dataset has links with other existing datasets (AGD database and Bushfire CRC Research Taskforce building and human surveys).

3.2.1 SHELTERING DATA

The coding developed for this project relates to information on types of shelter and activities while sheltering. Information was collected for a number of variables:

- The people involved in sheltering. The residential address and place of shelter(s) was recorded for each location relevant to an incident. Where known, data was collected on the number of people, their genders and whether they survived or perished while sheltering.
- The activities of people sheltering. Both intentions and actions were recorded as free text. In addition, a distinction was made between active and inactive behaviour. Active sheltering behaviour was characterised by some monitoring of the fire or actions to protect the shelter and occupants. Conversely, inactive shelter behaviour was characterised by a lack of monitoring and actions to protect the shelter and occupants.
- The type of shelter. Shelter type was coded into nine categories:
    - in house
    - in building (e.g. school, hotel, pub)
    - in other structure (shed, bunker, cellar, water tank)
    - outside in open space
    - outside behind a physical barrier
    - in water body (dam, swimming pool)
    - in car/vehicles
    - unknown
    - NA/defending outside.

- The detailed location of shelter inside structures.
- If multiple places of shelter were used, then each of the locations and types of shelter.
- The survival of the shelter. Whether the shelter survived was recorded for each incident and for each shelter (yes/no/NA).
- The final status of a location in term of fire impact (if data available). In each case these were categorised into:
    - destroyed
    - damaged
    - untouched.
- Additional information on house construction and defence. This information was recorded as free text in order to provide additional context regarding house vulnerability to fire exposure and the influence of occupant behaviour if the house survived.

3.2.2 SPATIAL INFORMATION

The spatial location of residential addresses and place(s) of shelter were recorded using Google Earth and Geographical Information System (GIS) software (ESRI ArcGIS) utilising the available geo-registered high resolution aerial photography and exiting spatial datasets.

The dataset also contained some variables derived from analysis of various databases and other spatial datasets. The spatial analyses built upon the work done for the Life Loss database (Blanchi et al., 2012), including the following spatial analyses:

- The distance to residence and between shelter(s) (where available):
    - straight line distance from a location of shelter to their place of residence
- The distance to forest and type of vegetation:
    - straight line distance from the location to the closest forest
    - calculation of the fraction of forest (as described by the NCAS forest layer) within 100 m of all locations. The arbitrary figure of 100 m was used in order to further understand the implications of its use as a definitive distance in building regulations (Standards Australia 2009)
    - type of vegetation at each location as defined in a variety of vegetation spatial data products.
- The fire severity (Kilmore area only)
- Post-bushfire building surveys (where available).
- Specific location details on the number of people, their behaviour and their survival. As each incident may have had many locations associated with it, the data was derived from the incident level data collection.
- The type of location where each individual sheltered was coded in the following categories (more detailed than at the incident level):
    - Bunker
    - CFA sheds
    - Commercial
    - Open space (Behind physical barrier, Open space, Oval)
    - Residential building
    - School

- Inside structure (Cool room, Garage, Shed, Spa room, Water tank)
- Vehicle (Driving, Stationary)
- Water body (Dam, Lake, Pool).

3.3 Qualitative analysis

Qualitative analysis of witness statements and interview transcripts was undertaken to explore residents' experiences of sheltering during the 7 February Victorian bushfires. Witness statements and interview transcripts were entered into the qualitative data analysis software NVivo v.10, which was used to manage the qualitative data and to assist with its analysis.

A coding framework was developed in which to explore, sort and group the data into relevant themes for a more detailed analysis. The framework was developed based on the aims of the project, previous work (Blanchi et al., 2014; Haynes et al., 2010; Whittaker et al., 2013) and also issues emerging inductively from the data (Kelle, 2007). A team, composed of three members, read and analysed the data from the different sources. The categories and themes into which qualitative data were grouped included:

1. Intention to shelter:
    a. as a primary strategy
    b. as a backup or last resort.
2. Planning and preparation for sheltering:
    a. before 7 February 2009
    b. on 7 February 2009.
3. Factors and decisions leading to sheltering or not.
4. Experiences of sheltering and exiting:
    a. where people sheltered
    b. how people sheltered, what they did
    c. when people exited and why
    d. challenges
    e. things that helped.
5. Examples of 'active' versus 'passive' sheltering.
6. Health issues associated with sheltering.
7. Future plans for sheltering or not.
8. Emerging issues.

3.4 Quantitative and spatial analysis

A range of statistical analyses were performed using the categorical data extracted from the interviews, witness statements, other sources and spatial analysis:

- Frequency analysis was used to describe the data collected.
- Contingency table analyses (cross tabulation analysis) were used to understand the relationship between two (or more) variables (e.g. shelter survival and distance to forest). A cross tabulation analysis is a two (or more) dimensional table that records the number (frequency) of responses that have the specific characteristics described in the table cells.

- Regression analysis.

Factors considered in the analyses included:

- The spatial location of shelters, including fatalities and survivors, were presented at both the incident level and for each fire. The geographic distribution was discussed in relation to other variables (shelter location category, fatality or survivor).
- The shelter location categories in relation to shelter survival, activity and decision making, distance to residential address (if relevant).
- The number of shelters used was considered.
- Relationships between shelter location, distance to forest, wind affected areas and fire severity were examined. The analysis only included location of the shelter with a precision confidence of better than 10 m.
- The difference between active and inactive behaviour during the shelter period were discussed.
- The influence of groups/individuals was considered.

3.5 Limitations and uncertainty in the data

Data on sheltering experiences were collected from a range of sources including VBRC witness statements and semi-structured interviews conducted by the Bushfire CRC Research Taskforce (Whittaker et al., 2009). The witness statements and interviews have a number of limitations as data sources. Members of the public were invited to submit witness statements for the VBRC or submit evidence to the VBRC. Self-selection bias means that this sample is highly unlikely to be representative of the wider bushfire affected population. The interview sample (*N*=611) covered the major fire complexes and can be considered broadly representative of what happened in different communities and locations. These interviews were semi-structured, which means that researchers asked a series of open-ended questions to explore key issues, but allowed interviewees to frame and structure their responses (Rubin et al., 2005). This process can provide rich, personalised narratives that offer unique insights into people's experiences and understandings of events and phenomena. However, questions were not standardised or specific to sheltering, caution should be taken when interpreting quantitative findings derived from the data.

Please note that findings from the analysis of witness statements and interviews are mainly *qualitative*. Nevertheless, researchers have attempted to convey whether particular experiences and issues were common or not by using phrases such as 'Many interviewees …' and 'A small number of interviewees …' The primary purpose of the witness statement and interview analysis was to provide *qualitative insights* into people's experiences and understanding of sheltering during bushfires.

A large amount of information on the 2009 bushfires was available to accurately determine the spatial location of the residence and shelter. A high accuracy level was obtained for most of the cases (precision of 10 m). In some cases, the location of the residential address or the location of shelter could not be determined and was not included in the spatial analysis.

Part 2 Result and discussion, and conclusion

4 Analysis of Black Saturday bushfires

Qualitative and quantitative data were analysed to better understand the sheltering practices of residents and the challenges they faced during the 2009 Victorian bushfires. As mentioned previously, the analyses aimed to answer the following questions:

- Did people intend to shelter or engage in preparation specifically for sheltering?
- What factors led people to take shelter during the bushfires?
- Where did residents shelter?
- What actions did residents take while sheltering?
- What are the risks and challenges faced by residents while getting to a shelter, sheltering and exiting?
- Is there a relationship between proximity to fuel or fire severity, and the residents' sheltering experiences?

The results section has been divided in four chapters due to the extensive range of data analysed.

- Intention, planning and preparation for sheltering
- Shelter type and beliefs about sheltering
- Activity and challenges during sheltering
- Failure of shelters.

Some of the sub-sections presented in the following chapters include only results from the qualitative analysis or the quantitative analysis, and some sub-sections combine elements of both approaches. In addition, case studies have been used to emphasise situations experienced by some residents while sheltering.

The database contains 325 incidents involving 169 fatalities and 861 survivors. Some of the spatial locations could not be identified and the data associated with those locations are not included in the spatial analysis (*n*=169 fatalities, *n*=838 survivors). As an example, each of the known locations of sheltering can be seen in Figure 1 for the Kilmore fire. The analyses presented in this report draw on various subsets of the data relevant to the questions being considered. To describe the data, frequency distribution, graphs and cross tabulation were used to display the number, and in some case the percentage (relative frequencies), of the variable value. It is understood that the sample might not represent the population of people who survived while sheltering (see Section 3.5). There is no intention to use these results as a statistically confident predictive model.

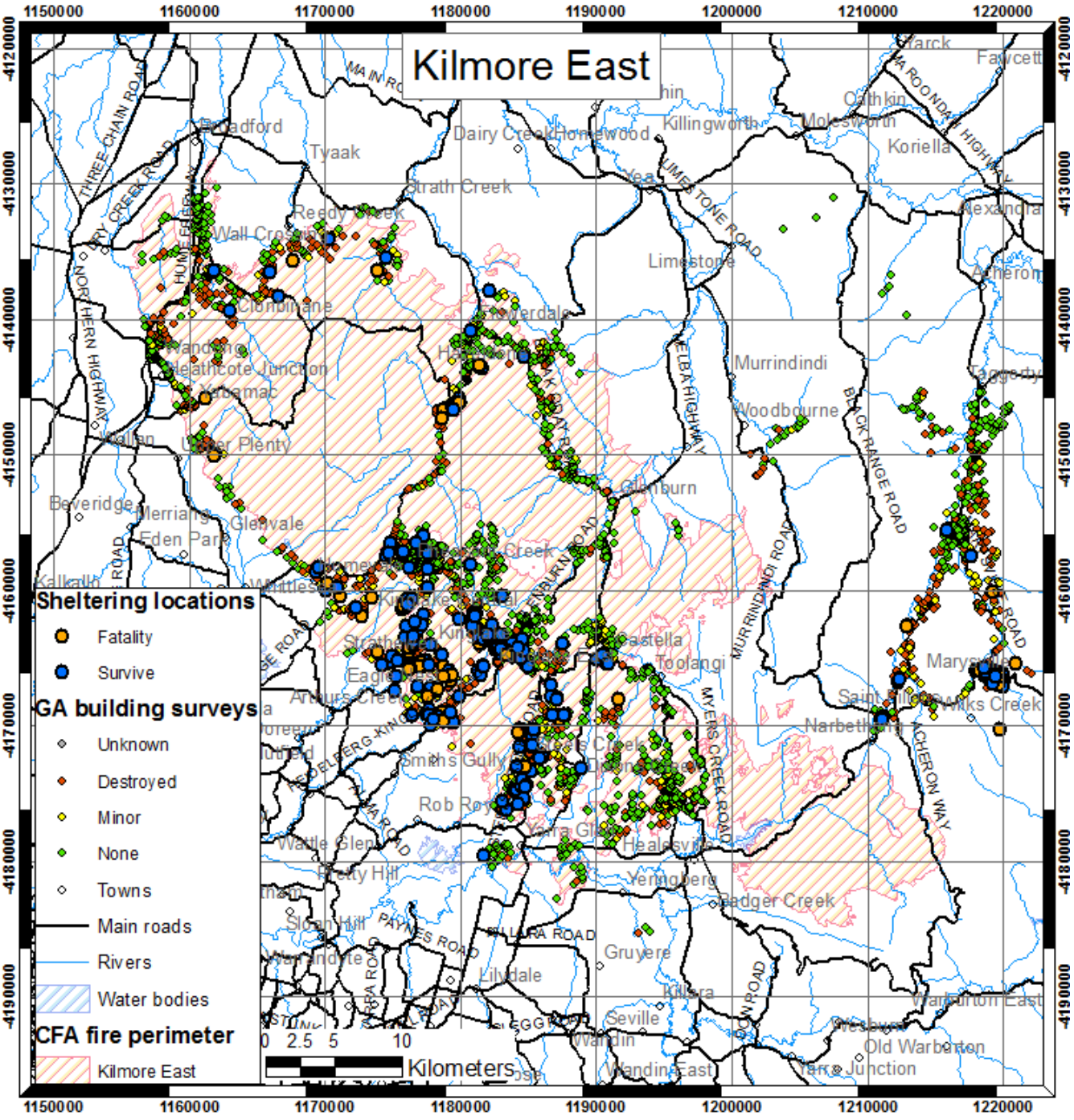


Figure 1 Sheltering location, building survey for the Kilmore bushfires (background map: Geosciences Australia main road and rivers).

5 Intention, planning and preparation for sheltering

This chapter presents the results of the qualitative analysis on intention, planning and preparation before the fire and give an insight on future plans for sheltering. The quantitative data on this topic were collected as free text, which made it difficult to categorise different intentions, planning and preparation measures undertaken by a group of individuals.

5.1 Intention to shelter

Many interviewees did not anticipate that they would need to take shelter during a bushfire. However, some residents did intend to take shelter either as their primary plan or as a contingency plan.

5.1.1 SHELTER AS A PRIMARY STRATEGY OR FIRST RESORT

A small number of interviewees intended to shelter throughout a bushfire as their primary strategy. These included people who intended to leave their house or property for a nearby place of shelter, those who intended to shelter inside their house or on their property while others defended, and those who sheltered inside their houses without attempts to defend or protect the structure.

A number of interviewees intended to leave their home or property for a nearby place of shelter. In Marysville, some residents had identified the cricket oval at Gallipoli Park as a safe place of refuge during bushfires. Similarly, some Kinglake residents had intended to take shelter at a local turf farm where they could shelter in the open under sprinklers.

> *My fire plan for the day was if it got that bad, that as the embers came, I would switch the sprinkler system on and leave, go to the oval.* (Marysville)

> *Our fire plan was to go to [place removed], which is on the main road there. It is a turf farm. They have got 100 acres of sprinklers and when there is a high risk fire they put the sprinklers on and they said, 'The coffee is boiling for you when you are ready.'* (Kinglake West)

> *I was clear in my own mind that I should go down to the oval, which is quite close to [place removed], and that if necessary I would take refuge in the lake.* (Marysville)

Other residents intended to shelter at a nearby house or property. Analysis of the interviews revealed a number of references to local 'safe houses' that would provide refuge for residents during bushfires. The issue of safe houses is addressed in Section 6.2, below.

Most commonly, residents who intended to shelter as a primary strategy planned to shelter in a house while other household members actively defended. Typically, men intended to stay outside and defend while women stayed inside, often to care for children, vulnerable household members, visitors and pets

> *We had all the proper gear. We had the kids in the bathroom, had all the windows sealed and wet towels around the house. We filled the bath because that's where the children were going to stay, in the bathroom, with the dogs ... I have always said I would never leave, it doesn't matter, I would never leave. If we had have gone, this [house] just wouldn't have been here.* (Kinglake West)

> *Because we had [a guest] there, I was responsible for her and so I couldn't help him. And from all the preparation, we were always told to stay in the house, [because] that was the safest place. So I thought, well, we have to go to the safest place, plus the fact that I truly believed we'd built a fireproof house. You know, we had an earth roof and in the middle part of the house we would've safe, it's like a bunker … So we'll be right, it will just pass over. So with full confidence I stayed inside*

the house with her, filled the bath with water and wet towels and did everything I could do to make it wet. (Steels Creek)

The plan was that I would be outside the house initially as the firefront approached, looking for embers. I would then retreat inside with X while the firefront passed and then I would go out or if need be both of us would go out and put out fires around the house, as we were advised to do. (Callignee)

Because we had the two-way radios, we felt that one of us could be in the kitchen and one under the house in the workshop if necessary, and we could still communicate. We did not have a particular room in the house in mind to shelter in, but we had all the doors unlocked and we have a number of doors on the front veranda so we could go in anywhere that we needed to from outside. (Steels Creek)

In some cases, other primary places of shelter were mentioned such as fire shelters, bunkers, cars, burnt areas, paddocks and sports ovals. Those places were also mentioned as backup plans or places of last resort.

My family's fire plan includes: …f. a family swimming pool for use as a shelter from a passing fire front. (Upper Plenty)

A very small number of interviewees intended to shelter inside a house or structure without another person attempting to defend it. A number of these residents believed their house would provide safe refuge because it was constructed from brick rather than timber. Typically, these residents had done little to plan or prepare for bushfire.

We thought we were going to be okay inside our residence. We thought that was going to be our refuge. Until all of a sudden we realised we weren't going to get out of this alive and took off. (Kinglake West)

5.1.2 SHELTER AS A BACKUP OR LAST RESORT

More commonly, residents described their intention to shelter as a backup if their plan to defend was unsuccessful. There were very few instances where residents discussed sheltering as a backup if they were unable to leave. Those who intended to stay and defend often envisaged that they would go inside during the main passage of the fire front and continue defending once it had passed (as advised by fire authorities).

Well, the fire plan was – it was a simple one. As I said, my main line of defence was the building, actually, as a refuge, so that I could withstand [the fire front]. Cause the fire passes over quickly. (Christmas Hills)

So in hindsight my preparations were fairly inadequate. But I guess I'd always had instilled into me the basic plan of you've just got to withstand that front. I think when the cloud came and it got dark I think that's perhaps when people panic then and got into cars and things, which I would never do. So you know I'm not saying it would have worked on a hillside where the fire was much more fierce. But here that basic plan did work of protect yourself from that radiant heat of the front and then get out. (Steels Creek)

Some interviewees had identified where they would go if they were unable to shelter inside the house. Anticipated places of shelter included cellars, bunkers, sheds, dams, swimming pools, water tanks, cars and open spaces. A small number of interviewees had considered that they might not be able to reach their preferred place of shelter, or that the shelter may have become unsafe, and that they would need to

shelter elsewhere. Many recognised that they could move onto areas of burnt ground to safely shelter from the fires.

> *If it got up there and set fire to the house, we would not have died. We would have just gone and stood in the paddock … We would have had burnt feet maybe but we would have just stood there. The fire had gone from there and we wouldn't have died.* (Humevale)

> *We had 'Plan A', 'Plan B', 'Plan C'. You know, the bore was going to protect everything because we have got taps right around the house. When that went up in flames we had all the buckets and everything in bathtubs, troughs. Kitchen sinks and everything full. That was 'Plan B'. 'Plan C', if the house catches fire, wait until the firestorm has passed, go out and find a part that has already been burnt in the bush.* (Kinglake West)

> *The 'Plan B' is downstairs underground. Obviously we've got wooden floor joists and wooden ceiling here. But we've got exits at the other side, at both front and back of the house. So 'Plan B' would have been if it is too hot outside, come in. If the house is on fire and say the pump broke down, we couldn't do anything about it apart from wet towels, then it would be walk out through the black stuff, into the black stuff, which wouldn't be terribly safe because of all the falling trees, but we would have probably survived that pretty well. So, yeah, there's always got to be a 'Plan B'. 'Plan C', running away, was like way, way, very far bottom of the list. Because I just know you don't.* (Castella)

> *Yes, I've got a plan B and a plan C for everything. … What were B and C? – Plan B was to evacuate the house on foot and to go to the Gallipoli Park oval.* (Marysville)

> *If the house burnt, we would retreat to the place of respite. This was going to be beside the 10,000-gallon concrete water tank on the south east corner of the house.* (Callignee)

5.2 Planning and preparation for sheltering

Levels of planning and preparation for sheltering varied substantially. Most residents' planning and preparation focused on measures to enable them to stay and defend against bushfire, or leave safely (see Whittaker et al., 2013). However, some residents planned for what they would do if they needed to take shelter, and some undertook preparations specifically to ensure their safety while sheltering.

5.2.1 PLANNING

As noted above, although many interviewees had not anticipated that they might need to take shelter during a bushfire, others had pre-existing intentions to take shelter as a first or as a contingency plan. Levels of planning for sheltering varied significantly among these residents. Some of those who stayed to defend did not have a firm plan for where and how they would shelter. These residents often envisaged that they would shelter 'somewhere outside', in a dam or water body, or at a neighbour's house. Others identified one or more specific locations where they would be able to shelter during the fire. These locations included inside houses and other buildings, in sheds, cellars, bunkers, dams, swimming pools, water tanks, cars and open spaces (particularly those that were already burnt). A small number of interviewees had even rehearsed their plan for sheltering. The varied levels of planning for sheltering are evident in the quotes below. A few residents mentioned building a bunker as a protection measure. Some people who planned to shelter had cleared spaces around their houses and other buildings.

> *If the house had caught early, I guess we would have found a space of refuge. But it's hard to know because it seemed like for about two hours there were moments when there was a lot of smoke out*

there. So I guess we had our blankets, we could get out and go under the blankets. I don't know … (Kinglake West)

I guess our solution is if the house was going, we'd run to the dam, so then you'd be – you'd be surrounded by the dam … Wet blankets, you know, wet blanket overhead and then go to the dam. We had talked all about that, rehearsed it all again on Saturday morning. (Yarra Glen)

We have an area under the house here, which is like a cellar, completely bricked in. And there are some air vents, but we had rags and things like that. If we needed to, we could block those … So the idea was that mum would go down there. So we even did a little dummy run in the afternoon. I took her down there, and sat her in the chair and said, 'If a fire comes, this is where you're going to be sitting.' And we had our drinks, a little Esky and things. We had a bucket with some wet towels and things like that. We had our dog, Toby. He was tied up under there. So that was sort of all ready. (Callignee)

[Residents] were concerned that we should take steps to have a 'Plan B' in case of another fire (our 'Plan A' being the sprinkler system I had installed earlier at the property). We came up with the idea of constructing a bunker on our property. (Kinglake)

5.2.2 HOUSE AND BUILDING DESIGN

Interviewees discussed a range of measures that were taken to design, construct and retrofit houses and buildings in order to improve the performance of the house during bushfires. Some residents constructed their houses from brick or mud brick in an attempt to reduce the number of combustible elements associated with their houses. A small number of houses had been built into hillsides or covered with earth to protect against flames and embers. Other measures incorporated into the design of buildings included concrete slabs, underfloor enclosures, double-glazed windows, windows shutters, Colorbond roofs and sprinkler systems.

And I knew that the first thing was – it's just like our own bodies, you know, our skin is our last line of defence, really, and it's the same thing. So the skin of the house – the actual building and the way it's constructed. The way I built it was to be built as a refuge, as I said, so it would withstand – so in there would be safe, and I was, as I said. (Christmas Hills)

I got shutters put over that front door, too. When we did it, people said to me, 'You've done it for security?' And I said, 'No, fires.' We should have had them on these windows, too, but I couldn't afford them. (Callignee)

We decided to stay. When I take you out the back and show you, you'll see our house is partially dug in from the hill and I think that was a help. Brick was another help. Double-glazing in windows was another help. No vegetation immediately close to the house and a colour bond [sic] roof. (Marysville)

5.2.3 PREPARATION

Most residents who sheltered during the bushfires undertook preparations with the primary aim of assisting them to stay and defend their property or to leave. Preparations that were made to assist in the defence of houses, such as clearing vegetation and blocking and filling gutters with water, increased the likelihood that residents could shelter safely, if only for a short period of time. However, some interviewees discussed preparations made specifically to enable them to shelter safely. Most residents who sheltered had baths, sinks and containers filled with water, and wet towels around the house. Some people put

shutters over the windows or pulled down blinds, and some moved furniture and other items away from the windows. Many interviewees described having protective clothing to wear while defending and sheltering. Residents often wore woollen clothes, full-length overalls, work boots, masks, helmets and gloves. Some of those who planned to leave but were unable to do so kept water and woollen blankets in their cars in case they needed to take shelter while evacuating.

> *We had put a hose onto the laundry, a house connection, so we could have an inside hose. I now want one in the kitchen – I don't care how unglamorous it looks. And one in the bathroom, because I think that would give you the reach right through the house. So we had the hose in the laundry – we filled up the laundry sink, we filled up the bath. We had buckets all through, lined up; so in the house I was just mostly watering down all the doors throwing buckets at all the edges of all the windows.* (Kinglake West)

> *We had the baths full of water and we had everything, well, we thought, under the house … We made sure that our baths and hand basins were full, everything was full of water, our garbage bins outside were full of water, everything, the wheelbarrow. Everything was full of water.* (Marysville)

> *We had a woollen blanket and a whole pile of towels in the bathroom so that if we got stuck we then had the water supply, the blanket to cover ourselves, the towels to block the smoke.* (Flowerdale)

> *All the fire shutters, bar one, were down on my house. So I was ready internally for the fire. I had the buckets, I had the sprayers and stuff ready. The fire cupboard is always stocked. I have ventilators, proper ventilators. My ex husband's a firey, so he stocked that pretty well before he left. I have stand alone water supplies in there. My house is on a gravity feed so if the power goes I've still got water into the house. I had fire shutters on all but two of the windows. I had a sprinkler system on the house. A sprinkler system on the stables. Stand alone water, two separate fire pumps, three lengths of hosing. I installed [the shutters] two years ago after the Kinglake fires up the road. I had a new sprinkler system on the house, which was a mister that sprays out. So as embers are coming in they don't get onto the roof, they have to go through the fog. I had the same one on the stables. Stand alone water supplies. I had two fire pumps – one powering the sprinkler system here, one by the stables. I was in my own protective gear including my ventilator masks and goggles and overalls, fire resistant overalls. All the animals were in the house.* (St Andrews)

> *Putting keys in every external door on the house and unsnibbing all of the internal fly wire doors (in case we needed to make a speedy exit); checking that heavy objects were on hand in every room in case we needed to break a window to get out.* (St Andrews)

A key finding from the interview analysis was that many residents were surprised by the arrival of the fire and did not have time to enact their final, last minute preparations. Typically, these residents had undertaken a significant amount of preparation on the day such as setting up fire pumps, wetting down the house and filling bins and containers with water. However, the sudden arrival of the fire meant that they were unable to complete all of the preparations they had planned for.

> *We had a really good fire plan. We had pop rivets and sheeting for the windows and everything we had ready to go. It was all by the front door. Yep, didn't have time for any of that. We only had time to run around, because it was a 40-degree day, and find his boots and jacket and get them on and then it was 'Go' … Didn't even have time to go down and get a mask or anything …* (Kinglake)

> *And buckets all around the house, which we had also. Then, our deal was that we were going to stay inside, you see. We thought as far as being safe and that would be the fire plan for a normal bushfire, say, and wait for the fire front to move through. We've all gotten that sort of information*

over the years. But yeah, there was just too much coming. We didn't want to be around for that. We didn't have time to put anything into action. (Narbethong)

I got the sprinklers going, which is on the roof on the whole exterior of the house. Got that pump going, got the sprinklers going, wetted the whole place down. Got a couple of buckets of water, got my bushfire clothes on and then we were supposed to leave the house to get into the fire bunker, the concrete bunker, and it was too late … We didn't get to instigate our bushfire plan in its entirety, not by a long shot, not by a long shot. But we really didn't have the time frame to do that. We all got caught out. (Kinglake)

5.3 Future plans for sheltering

When asked if they would do anything differently in a future bushfire, 45 interviewees and 11 witness statements discussed future plans for sheltering. More than half (*n*=30) said they would consider building a 'bunker' or other structure in which to shelter during bushfires. Some were adamant that personal bunkers should be compulsory for all people living in designated bushfire risk areas. Where some interviewees had carefully considered the design, construction and location of the structure, others had simply identified a need for a place to shelter as a last resort. A small number were confident that they could construct 'fireproof' structures that would protect them throughout a bushfire.

I'm going to build a bunker, a fire bunker, where that little woodshed was. Going to sink that at, you know, several feet, and I'm just going to build one, you know. (Kinglake)

I'm definitely looking at a bunker/strike shelter in a cleared area for the future. Not so much for my family to stay in, but if you were caught unawares. (Castella)

So I think in the future there should be a communal bunker that can hold us all, or a few of them, or have one of your own, have one yourself. (Marysville)

We're going to build a bunker … Whether it's a steel container, like a shipping container, and bury that in the ground. And sprinklers on the roof … Not plastic sprinklers. We'll put metal sprinklers up there. Probably have a little generator or something inside the house, perhaps in the back room … in case the power goes out ... (Kinglake)

I'm going to build a shed out the front … It will be a fire proof shed, totally fireproof … It will be on a concrete slab, made out of fire retardant steel studs, a 120 fire rating, which is a two-hour fire rating, which means you can have radiant heat burning around it for two hours before it collapses … Fireproof doors, fireproof window. And I'll make sure that my fire clothes and fire hoses, pumps and everything will be stored in there … And then, worst case scenarios, can go in and close the door and you'll be safe. (Steels Creek)

The different plan is to build a bunker. Definitely build a bunker, have a generator and a tank underground just so I don't have to ever do that bit [sheltering in a car] again. Like, I'm quite happy just to go 20 feet into a bunker … The fire usually goes through within 10 to 15 minutes, so if I've got it set up correctly with the two doors, you know, I should be able to tell when it's safe again and do that. My neighbour's going to put one in as well. (Kinglake)

If you set yourself up a fire bunker, you can start it all up, go in your bunker, wait one hour, and come back out again. (Hazeldene)

Many residents also supported the idea of having community bunkers or refuges. Despite widespread support for bunkers, some interviewees were concerned that such structures would not provide adequate

protection during 'extreme' bushfires, like those experienced on 7 February. In particular, residents feared that bunkers would fill with smoke, that oxygen would be 'sucked' out, and that the structures might collapse onto occupants. It was also noted that the presence of a bunker could encourage residents to wait until the last moment before deciding whether to stay and defend, leave, or take shelter:

> *I unfortunately think bunkers tempt people to stay … I've been into a couple of people's bunkers and they've got ash in them, and the fact that there was no air anywhere, there wasn't anything to breathe. I mean, being in a bunker, you might have just died anyway. Why tempt people to just stay longer than they should have?* (Strathewen)

> *They were talking about getting bunkers in houses but I don't think they will work. People up here will store their [things] in their bunkers and when it comes through they won't get in it, and you know, all it takes, some fire sucks in the holes and stuff …* (Kinglake)

> *People who had bunkers in their places, didn't make any difference to them. [Name removed] up over here, apparently he was in his bunker and the house collapsed on him. That was the end of him … Another bloke up here, well, they got out but they had an underground cellar in their place and the house collapsed into that. So they always thought they'd go into that. Well, if they were in there they wouldn't be here.* (Humevale)

> *They'd had a meeting and they were talking about suggesting that people build concrete bunkers, and I said to her, 'Well that's a good idea, because you have to have an air source.' And I said, 'Any air source relies on a generator and, if your generator blows up or the plastic melts, then you're down inside a bunker all filled with smoke, so then you can die down there instead' … They don't work – they might work on a computer model … [they are] not going to work in real life. And besides, I'm not running out of my house so that I can leap into some bloody concrete bunker that's half way up my yard. And what do you do if someone knocks on the door and says, 'Let me in'. Do you open it, and find out that you're surrounded by flames and there's 30 people and you've only got room for five? 'Well, sorry, but you can't some [sic] in' … For me, they're just knee jerk reactions.* (Kinglake)

A small number of interviewees explained how they would design and rebuild their houses to enable safe sheltering in bushfires. Anticipated features of such houses included the use of fire resistant materials, fewer points on the house for embers to lodge, sprinkler systems on roofs and larger cleared areas around the house. Some residents were also considering building their houses into hillsides and covering them with earth.

> *I'm going to build a grey block, besser brick house, with Hebel aerated concrete panels. And obviously with a little bit of Colorbond infill, double glazed with shutters, and basically no exposed timber, with a full sprinkler system over the whole place.* (Christmas Hills)

> *The plan wouldn't change [to leave], but the house design would change. I think we are going underground. Wombats seem to survive all right … From what we know, the block's going to suit an underground house because you need a northerly aspect. So, you know, that doesn't mean that we couldn't actually stay in the house if we got caught, because the house that we would build would have a refuge in the house, and the house would be pretty good in and by itself.* (Koornalla)

> *We are currently in the process of designing our new house. We are going to build down into the hill so that it is protected – mainly from the afternoon heat and sun, but also from fire. … We are going to set the house in a mound to the south-west corner and infill the area between the house and that mound with earth. That should provide further protection from fire and from the cold south-*

westerly winds. We have decided to install a bunker and it will be between the house and the mound. (St Andrews)

5.4 Summary

The analysis of intentions, planning and preparation before the fire showed that most people had not anticipated they might need to shelter during a bushfire. Only a small number of interviewees intended to shelter as their primary strategy. Of those who had considered sheltering, most common was an intention to shelter for a short period of time during defence or if defence failed. Levels of planning for sheltering varied significantly among these residents from a vague to a specific location.

Most of the preparations undertaken by residents were undertaken with the primary aim of assisting them to stay and defend their property or to leave safely e.g. woollen blankets and water in cars. However, these preparations ended up increasing their safety when they ended up having to shelter. Future plans for many interviewees involved building a 'bunker' or other structure in which they could shelter safely. Although some questioned the safety of bunkers. Only a small number of discussed future plans to design their homes in a way that would enable safe sheltering in bushfires.

6 Shelter type and beliefs about sheltering

The chapter presents the different type of shelter used and discussed some beliefs about sheltering related to the safety of the shelter.

6.1 Shelter type

Sheltering can occur in a range of different places such as houses, sheds, bunkers or public settings. Occasionally people shelter in open spaces such as sports ovals or paddocks, alternatively they find protection in pools, dams or rivers. When people are caught in a fire, they seek refuge and protection from the radiant heat and smoke, which are the main killers. Therefore, finding shelter is about getting protection in a structure, a succession of structures or under cover. In some cases, successive shelters were used in order to find protection.

These refuges may take different forms according to specific geographic constraints, needs and protection available. While the domestic house is the most likely option (see Table 3), other choices can be made depending upon the situation at the time.

Table 3 Number of incidents by shelter type.

Shelter type	First shelter	Second shelter	Third shelter
In building (e.g. school, hotel, pub, etc.)	13	2	0
In car/vehicles	31	11	1
In house	211	4	3
In other structure (shed, bunker, cellar, water tank)	17	6	0
Outside behind a physical barrier	20	15	2
Outside in open space	10	15	1
Water body (dam, swimming pool, etc.)	6	5	2
Total number of incidents	308	58	9

Table 4 describes the number of people sheltering in different shelter types. Sheltering inside a house or other structure accounted for 63% of the sample. Interestingly, more than 120 people (12%) sheltered inside commercial buildings such hotels, pubs, wineries and ski huts. A large number of residents and fire personnel (in the order of tens or hundreds) sheltered at the CFA in Kinglake, Kinglake West and Dixons Creek inside the CFA shed or inside vehicles on the sports oval. The numbers of people sheltering at CFA locations provided in Table 4 are only examples extracted from the interviews and the witness statements (as precise information on people sheltering at these locations was not available). Community places of refuge and safe houses are discussed in Section 6.2[24] alongside results of the qualitative analysis.

[24] For more information on community places of shelter see McLennan et al. (2010)

Table 4 The number of people sheltering categorised by shelter type and subcategory, if available (from the spatial dataset).

Shelter location/type	Number of fatalities	Number of survivors	Total
Bunker	**2**	**9**	**11**
CFA (indicative numbers from sample)	**0**	**11**	**11**
Kinglake	0	6	6
Kinglake West	0	5	5
Commercial buildings	**4**	**120**	**124**
Open space	**36**	**83**	**119**
Behind physical barrier	16	50	66
Open space	20	30	50
Sports oval	0	3	3
Residential building	**109**	**496**	**605**
School	**0**	**9**	**9**
Structure	**6**	**23**	**29**
Cool room	1	unknown	1
Garage	1	6	7
Shed	1	11	12
Spa room	3	unknown	3
Underneath house next to water tank	0	1	1
Water tank	0	5	5
Vehicle	**12**	**54**	**66**
Driving	0	7	7
Stationary	12	47	59
Water body	**0**	**33**	**33**
Dam	0	13	13
Lake	0	1	1
Pool	0	19	19
Total	**169**	**838**	**1007**

6.1.1 MULTIPLE SHELTER LOCATIONS

Some residents had to seek shelter in multiple locations, to a maximum of three shelter locations. A summary of these data showed that 84% of people survived in their first location of sheltering. Subsequently, of the 12% of people who moved to a second location, 87% survived. Finally, 2% of people moved to a third location where all of them survived (see Table 5). An example of multiple shelter location is given in Case Study 1 (Figure 5) in Section 6.1.7.

Table 5 Number of shelter locations.

Shelter location	Number of fatalities	Number of survivors	Total number of people
First (frequency and percentage in row)	151 (16%)	800 (84%)	951 (100%)
Second	18 (13%)	121 (87%)	139 (100%)
Third	0	17 (100%)	17 (100%)
First (frequency and percentage in column)	151 (89%)	800 (85%)	951 (86%)
Second	18 (11%)	121 (13%)	139 (12%)
Third	0	17 (2%)	17 (2%)

The number of people sheltering at several shelter locations is shown in Figure 2, taking into account the type of shelter for each sequence. One of the most common places to shelter was inside residential buildings; 584 residents sheltered inside a house as their first location of shelter (including 105 fatalities and 475 survivors). The most prevalent place of shelter for the second location of shelter was in the open space (*n*=64).

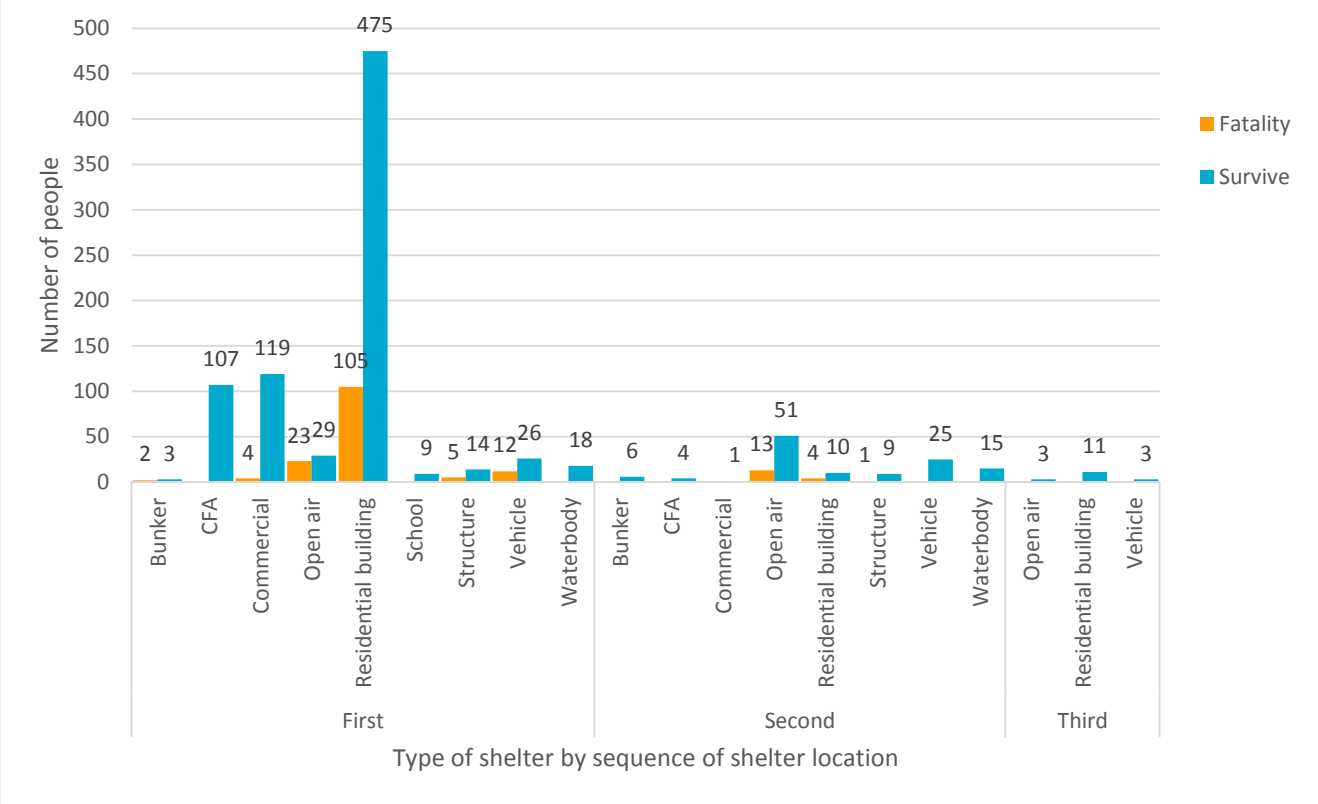


Figure 2 Shelter type used by each person at each progressive sheltering location (from spatial data).

6.1.2 DISTANCE TRAVELLED BETWEEN SHELTER

The following section describes the distance travelled between shelters and the distance from the residence where the fatality occurred in open space. Data was collected on the distance between sheltering locations (where those locations could be determined). These distances fall into two categories: the distance between used shelter locations and the distance between the first shelter location and the location of the residence of those sheltering. The accuracy of this data is approximately ±10 meters. Several

people could come from different locations to end up at the same location and conversely many people could end up at a different location that originated from the same location.

The distance travelled between locations was assessed given the survival of the people sheltering. The range of distances travelled between the first and second shelter location for fatalities was 13 m to 380 m and for survivors was 1 m to 7.5 km. The average distance travelled to a third location (of which there were no fatalities) was 122 m.

Generally, a larger proportion of survivors did not travel very far from their original shelter location (47% of travel was within 50 m) compared with fatalities (24%) (Table 6). Data is presented as a frequency percent to allow for comparison of the survival categories.

Table 6 The distance travelled (in m) between shelter locations, by distance category, for each survival category (*n*=77). Note all distances are ±10m.

Travel distance (m) ±10m	Survival	Fatality
0–50	47%	24%
50–100	22%	24%
100–150	3%	0%
150–200	2%	24%
200–250	7%	0%
250–300	3%	18%
300–350	2%	0%
350–400	0%	12%
450–500	5%	0%
>500	10%	0%
Total	100%	100%

The distribution of the distance travelled from one location to the next, given the damage status of the location that was left, is presented in Figure 3.

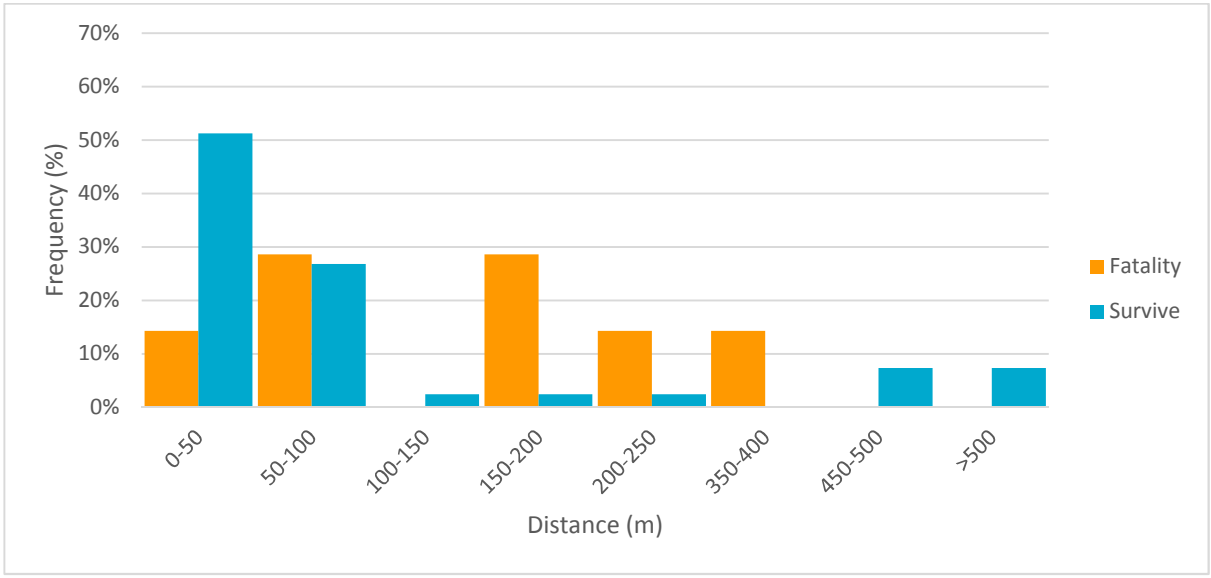


Figure 3 Histogram of frequency (as a percent) of distance travelled between locations for destroyed a shelter exited (*n*=55). Note that structures where the damage was not verifiable were not included.

Table 7 presents the distance travelled by fatality from their place of residence, 18 fatalities were found to have occurred in close proximity to the home (<20m). For three cases, the house was only damaged and could have been used as a shelter.

Table 7 Distance from residence and residential status (for fatalities).

Action	Distance from residence (m)	Number of fatalities	Residential status
In the carport, (while evacuating fell down in front of burning vegetation could not be rescued)	1	1	Destroyed
Veranda (1 fatality inside, 1 outside, presumably defending)	1	1	Destroyed
Back door (1 fatality inside, 1 outside, exiting or entering?)	1	1	Destroyed
Corner of the house trying to go to bunker	1	3	Destroyed
Overcome while fighting outside	2	1	Damaged
Front yard next to burnt out ute	5	1	Destroyed
1 fatality 6 m from house, 1 fatality inside	6	1	Destroyed
Planned to go to the dam but died close to his house	6	1	Destroyed
Probably caught outside unaware of the fire arrival	8	2	Destroyed
Sheltered in house, when house ignited, tried to find a shelter outside, could not make it to the dam due to smoke and intense heat	15	4	Destroyed
Trying to escape and get to a shed, found close to neighbour's house	90	1	Damaged
Probably trying to implement fire plan and evacuate	2 and 100	4	Destroyed
1 fatality outside, 1 fatality 210 m away, across the road in a cleared area, suggesting he had tried to run from the fire and seek shelter in the nearby dam (60 m from dam). 3 fatalities inside	2 and 210	2	Destroyed
Tried to escape a burning house, some did not exit, or were affected by fire outside	100 and 166	3	Destroyed
Trying to evacuate to neighbour's house in car, car got stuck, tried to get to the house by foot, could not reach it (200 m from neighbour's place)	230	1	Destroyed
Evacuate to Gallipoli, could not find her way	370	1	Destroyed
Was evacuating on foot someone else tried to help but could not find fatality because of smoke	440	1	Destroyed
Try to evacuate in separate cars, overcome by the fire	890	2	Minor damage
Evacuate by car and ran into a tree, tried to shelter at different place on foot, 3 were overcome by fire and smoke, 2 survived	2350	3	Destroyed

6.1.3 SHELTERING INSIDE A HOUSE (RESIDENTIAL BUILDING)

The quantitative analyses showed that 60% of people sheltered in a residential building (*N*=605, in Table 4). In most cases, residents took shelter inside the house during the passage of the fire front and then returned outside to defend their property. Occasionally, some members of the family (often younger or elderly persons) stayed in the house before and after the passage of the fire front.

> *We stayed inside for probably 10 or 15 minutes, something of that order because that is when it was burning, the radiant heat is ferocious. From inside, … we could watch the balls of flame hitting the deciduous trees all around the house and flames would go in and smoke would come out and we simply waited until balls of flame stopped going through the trees because if you were in the way of those balls of flame you were going to get fried just like the leaves were. When everything stopped burning outside we went outside to put fires out.* (Buxton)

The location or movements of people sheltering in the house varied substantially. Some people sheltered in a specific location such as a bathroom (see also Section 6.3.2), or pantry with poor visibility to the outside conditions or in other parts of the house such as bedroom, hallway, kitchen or laundry. Some people sheltered under the house in a cellar or workshop. Others moved around the house and monitored the conditions of the fire outside and potential ignition inside the house. In some cases, advice was given to stay low, to reduce the effect of smoke and heat, or below a window line to protect against flying objects. One resident reported having closed curtains or shutters to hide the fire from children.

> *We sheltered in the hallway, with the bathroom door open so that we could access water and towels … I estimate that we had been inside for less than one minute at this point. We decided that we should take a look to see whether the fire front had passed.* (St Andrews)

> *The pantry, which provided shelter to save five people and a dog on 7 February 2009, was in the centre of the house but on the south wall. I always considered that logically a bushfire would attack, from the north or north-west, so the south side is the coolest and safest side of the house.*
> (St Andrews)

> *As an added precaution, I told everyone who had taken refuge in my house to sit in the kitchen with their heads below the window line whilst the fire front passed. I didn't know how the gas bottles would behave and I thought that they might jet about and fly through the windows.* (Marysville)

A large number of people (102 incidents involving 276 people) experienced structural failure of the house while they were sheltering. They faced major challenges and issues detailed in Section 8.

The location within the structure (when known) was recorded in Table 8 to better understand the behaviour adopted by fatalities and survivors and the modes in which the house may have lost its tenability. The results showed that 37 % of people sheltered in a room with poor visibility to the outside mainly bathroom (58 people sheltered in bathroom including 38 fatalities) and also rooms under the house (which include enclosure under house and cellars). This is consistent with previous studies on fatalities in Australia (Blanchi et al., 2012) showing that 41% of the fatalities with known locations occurred in a room with reduced visibility to outside conditions (bathroom, enclosure, laundry, study, toilet block, bunker).

Table 8 Details of shelter locations inside houses.

Shelter location within house	Number of fatalities	Number of survivors		Total number of people
		Houses destroyed	Houses survived	
First	**105**	127	348	**580**
Bathroom	38	Unknown	20*	58
Pantry/Storeroom under stairs	0	7	Unknown	7
Cool room	2	Unknown	Unknown	2
Enclosure under house	4	Unknown	Unknown	4
Cellar	2	Unknown	5	7
Cellar under house	0	1	Unknown	1
Under house	0	Unknown	3	3
Bedroom	9	Unknown	Unknown	9
Entrance	9	Unknown	Unknown	9
Hallway	0	3	12	15
Kitchen	20	Unknown	5	25
Kitchen and moving throughout	0	1	Unknown	1
Laundry	3	Unknown	Unknown	3
Bathroom with external door	1	Unknown	Unknown	1
Lounge	3	Unknown	Unknown	3
Study	6	5	Unknown	11
Sun room	1	Unknown	Unknown	1
Veranda	0	2	1	3
Upstairs and downstairs workshop	0	Unknown	10	10
Back of house	1	Unknown	Unknown	1
Move through	0	43	Unknown	43
Room away from fire direction/Lee side of house	2	Unknown	2	4
No information available	4	65	290	359
Second	**4**	**5**	**5**	**14**
Study	4	Unknown	Unknown	4
No information available	0	5	5	10
Third	0	**1**	**10**	**11**
No information available	0	1	10	11
Total	**109**	**133**	**363**	**605**

* Most cases are children sheltering in the bathroom sometimes unsupervised or partially supervised (there is evidence where the priority of saving the structural integrity of the building led to unattended children being placed with pets in the perceived best sheltering place, the bathroom).

6.1.4 SHELTER IN OTHER STRUCTURES AROUND A RESIDENCE

A number of structural buildings around the main residence were used as shelter such as sheds, fire bunkers, water tanks, cool rooms, and kennels (see Figure 4). They were often used because they were the

closest option to those caught outside while defending and also as a secondary shelter when the first shelter, usually the house, had failed. In some cases, residents found it was safer to shelter in other buildings in the property and discussed the different options they had available for sheltering. However, a previous post-bushfire study highlights that some structure, such as outbuildings, were more readily lost compared to the main structure and hence represented a significant source of thermal exposure to surrounding structures (Leonard et al., 2005).

> *We were in real trouble and we couldn't shelter outside any longer because of the smoke and heat. The five of us got together at one corner of the house and decided what to do. I remember that we talked about running to the dam but we decided that it would be better to hide behind the concrete water tank. We used the water in my esky to wet our heads and our shirts and we sat behind the tank, hoping that we would be able to hang on for five or ten minutes, while the worst of the fire passed us by. That didn't work. Less than five minutes after we got to the tank, the house was burning really badly inside and out and it was then that we decided to get into the tank.* (Callignee)

> *I told [other resident] that we should evacuate from the house and I took his hand and led him out of the house and down the back steps which were already on fire. We then ran across to the nearby shed and went inside. The shed had been hit by the fire front but it had not ignited.* (Callignee)

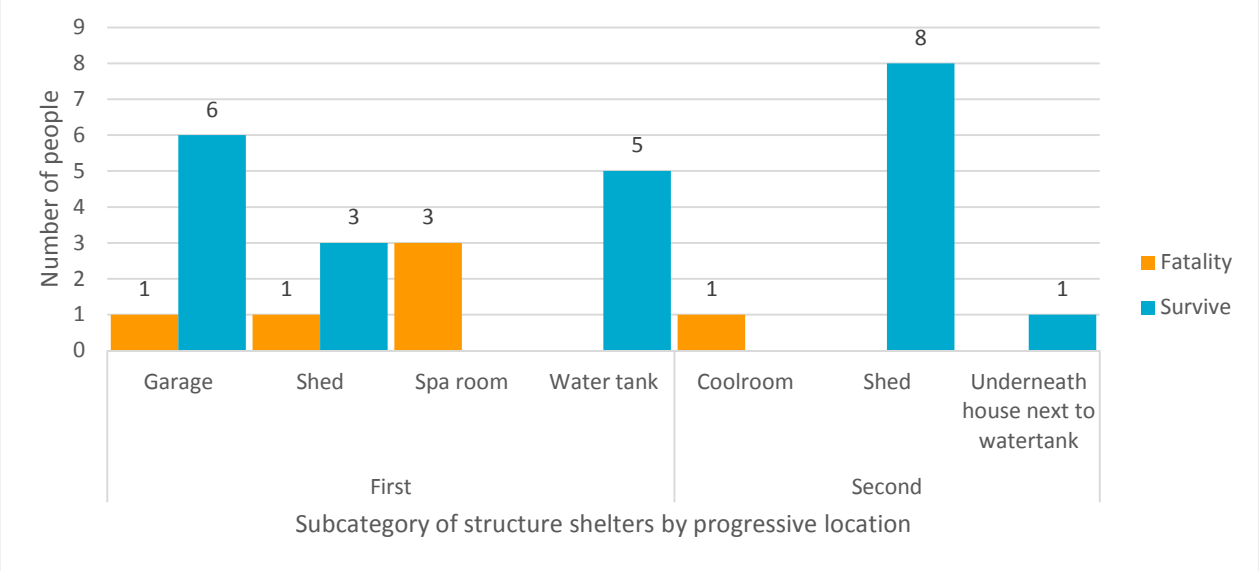


Figure 4 The status and subcategory of structures used for shelter, by progressive location number.

6.1.5 VEHICLES

Many people fled their property by car. Most of these people found shelter in a stationary position in an area cleared from vegetation (driveways, burnt paddock) or in a community place of refuge such as a sports oval or golf course. A few residents sheltered in their cars whilst driving around to protect themselves from burning elements. Overall, residents experienced difficulties due to poor visibility, obstacles and burning objects. Interestingly, some residents reported issues related to leaving in separate cars where could not follow each other or lost track of the other cars.

> *As I sat inside my car, it became darker and darker and the glowing sky became littered with large embers swirling in the ferocious wind. … My engine was switched off and I wasn't wearing my watch so it was difficult to get a sense of the timing of what was happening. I saw that a building just across the road from where I was parked was on fire. Suddenly there were embers all around and the car started to shake violently from the wind.* (Pheasant Creek)

6.1.6 WATER BODIES

Different types of water bodies (e.g. swimming pool, dam, lake, open spa) were used by residents, often as a secondary location of shelter. Residents reported that they needed to be sufficiently close to the house, to be able to re-enter them, but also not too close so as to be affected by burning objects (house, shed). Some residents mentioned that they used fabric (woollen blanket, towel) to protect themselves against the effect of the fire front and burning objects.

Swimming pool

They [neighbours] were confronted with the fire at the bottom of their drive, drove back, were going to get back into their swimming pool and half the house collapsed into the swimming pool. They then proceeded to get into their dam where they survived in the dam next to a wallaby. (St Andrews)

I realised then that I had to abandon the pump and run for my life to the pool, where [3 residents] were already sheltering with our dog inside the pool and under woollen blankets. At about 5.45 pm, I was in the pool and the fire front passed over us. It lasted for 20–30 seconds. (St Andrews)

Lake

She decided to drive out with the convoy … I then walked over to the lake, left my cameras on the bank, and got in. I took shelter on the lee side of the little island in the lake. (Marysville)

6.1.7 OPEN SPACE AND OPEN SPACE BEHIND PHYSICAL BARRIER

Some residents took refuge in open spaces close to their houses such as burnt paddocks, non-combustible driveways, olive growth, or further away at community sports ovals or school grounds, sheltering in their car, or in rare cases, standing outside. Again, people mentioned difficulties getting to the place due to poor visibility and burning obstacles.

It's time to get somewhere to safety. 'Where did you go then?' I went to Gallipoli Park oval. I knew it was a large open area with a little river beside it, the Stevenson River. I drove about 40 kilometres an hour through the smoke and embers, over some branches. It's about a half kilometre drive. But in the smoke I missed the turnoff to the Gallipoli Park oval and overshot by a few hundred metres. But, once I saw Bruno's Sculpture on the side of the road, I was able to double back and get to safety. (Marysville)

Shortly after that happened, somebody told me that there was a hole in the fence, and I saw that CFA vehicles were driving onto the centre of the oval [Gallipoli], so we moved the Fairmont onto the oval and moved the Land Rover to a spot between the lake and oval where it was away from the burning trees. (Marysville)

The smoke was very thick and pungent, but the fires provided enough light to see where we were going. We all marched in single-file hurriedly down into the middle of the back paddock, which contained our olive grove, and covered our mouths and noses with the wet towelling. We lay face-down on the ground in the olive grove after helping each other place the towels and dressing gown over the top of us. (Kinglake)

Many people mentioned sheltering behind a physical barrier to protect themselves against the effects of the fire (see Case Study 1 in Figure 5 and Figure 6). Residents defending their houses mentioned several times the need to shelter around the house, behind water tanks, sheds, cars or tractors while defending outside. In a few cases, people evacuating a burning shelter had to temporarily find protection behind a physical barrier such as a car, machinery, carport, trees or fences.

> *Fortunately, I was standing right next to a 60,000 litre concrete tank that was full of water and I believe this was part of why I survived.* (Kinglake)

(a) Fire attack on the house (in red) and movements of residents (in blue) (photo courtesy of resident)

(b) Third shelter used behind physical barrier (metallic sheet) (Photo courtesy of resident)

Summary:

- Intention: Stay and defend
- Preparedness: Well prepared
- Summary: Three people defending their house, retreat inside, the house caught on fire and have to exit, first shelter around the house as the fire move around them (a), then sheltered in an in ground pool behind metallic sheet (b).
- House: Destroyed
- People: 3 people (survived)

Account from resident:

> *I knew the inside of the house was not safe any longer, we need to be outside very quickly, they grab the dog. My daughter had wet blanket and we were heading outside with blanket. We step outside the backdoor on the sheltered side … We are at the back door at the corner. Under the verandah, sheltered by the house from the wind and the heat, my wife and daughter got under the blankets with the pets ... There was enough heat to ignite the fascia and the timber of the verandah … I was able to stay out with long sleeves, hat, goggle, dust mask P2, … I had a fallback position I could crawl under the blanket with the girls in case of danger… Then the wind changed again, and brought the heat into that corner we were sheltering. So we got up and moved around this corner of the house, again the girls under the blanket and me walking checking things. And then the wind changed again, we had to move around to this face of the house, by that stage the house was pretty much fully involved … and that 's about when everything peaked, the peak was sort of in this space … staff was still burning, the fire front has gone passed, but this was hot air it was not fire as such … I thought it was life threatening hot air if we stepped out we will be burnt. It was clear we won't be able to stay here for very much longer. So we went through the options. I am down at plan D at this stage. We looked for plan D, big concrete water tank here, easy enough to get into but probably fairly difficult to get out off … an option but not great and we had to get through burning stuff to get to it. The veggies garden was here and was still green so we could go lay down between the terraces but still have to go though burning things. We have an old above ground swimming pool up there. There was a break in this hot air, I picked the time when it settle it.*
>
> *It was half full of water It was still standing, we came up here, and I threw my wife and my daughter. The sides were too hot to touch; I cleared the side and jumped in. We were sitting in the water with the blankets over us, chatting … I felt safe and comfortable . At that point somewhere around the wind change came through (around 6pm). That was the South-westerly wind change the other changes were fire behaviour [due to the effect of the smoke column] … I don't recall the fire front going passed. This was more catastrophic fire … after the wind changed, the wind speed increased, the wind screaming, again it's somewhere up into the 150-200km/h mark. The winds were extraordinary, the wind was strong enough to blow the side of the pool, the liner failed and the water run out. We have been using this pool for irrigation water it has about this much mud in the bottom of it. We snuggle down the mud. We put the blanket over us. The wind change and blew, the steel collapsed over us and created a shelter over the top of us. We stayed in there I don't know … Probably, I think 20-30mn. I guess around 7pm everything calm down, the smoke disappeared, so I stuck my head up and I had a look around.*

Figure 5 Case Study 1: Example of multiple shelters location and shelter behind a physical barrier.

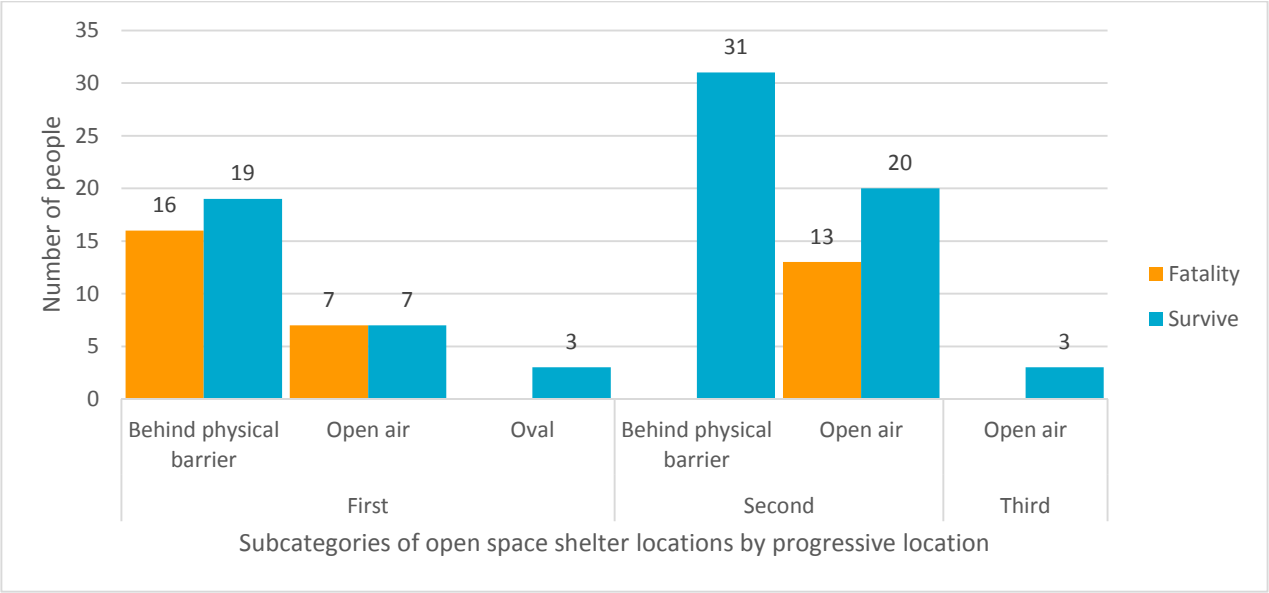


Figure 6 The status and subcategory of structures in open spaces, by progressive location.

6.2 Safe houses and community refuges

Analysis of the interviews identified a number of references to informal, locally organised 'safe houses' and 'community refuges'. One 'safe house', located in Kinglake West, was visited by a number of local people during the fire (see Case Study 2 Figure 7). The house was occupied by a CFA member who had prepared to stay and defend. While numerous interviewees referred to this house as a 'safe house', it is unclear how it was informally designated as a place for local people to shelter. Some local residents appear to have arrived at the house in the early stages of the fire and were asked to leave by the occupant, who did not want to be responsible for their safety. Residents who arrived during the main part of the fire sheltered at the house.

> *We were at the safe house for maybe ten minutes or more. The fire arrived at the safe house. The CFA showed up and said, 'Anyone who wants to leave better leave now.' So we took that advice and left the safe house.* (Kinglake West)

> *She was set up. She had diesel generators and pumps, she had water, alternate electricity supply and she had garbage cans around the house with mops in it full of water ... Then all of a sudden everybody's telling us to get out and leave and we look down the hill and we were full of smoke and there was just this raging furnace coming up at us so quick, you know. [Name removed] sort of felt like she didn't want to be responsible for our lives. So she told us to leave. We left … She stayed and fought and saved her house. But she didn't want us there because she didn't want responsibility for us as well. So we went with the smoke over both sides of the road going out, National Park Road. I got to the intersection of the Kinglake Road there and National Park Road and if I'd turned left into Kinglake West I'm driving into the fire, so I went right, I went up to Kinglake and we sheltered in the fire shed up there, the CFA shed.* (Kinglake West)

> *We went to two other houses, on the right-hand side down the road. As they burnt, we grabbed the kids and that house's occupants, and moved on to the next one. And [name removed] place, the big brick one on the left-hand-side, that's where we finally took refuge. She had a room underneath the house. The house is built on an angle and there's a room, almost a garage, underneath. And so we put all the kids in there, and all the animals. There were kids and dogs and cats everywhere. And we all went out to help fight the fire.* (Kinglake West)

A house in Kinglake was also identified as a local 'safe house'. An assessment by CFA after the 2006 bushfires had identified at least one house in the street as unsafe because of the proximity of vegetation surrounding the house. Another house in the street was apparently assessed as being safer because it was built of brick and had a generator, fire pumps, hoses and sprinklers. A number of people died at this address.

> Interviewee: *They ran up to the house that had been designated as a safety house.*
> Interviewer: *Are they okay?*
> Interviewee: *No.*
> Interviewer: *[…] How did they decide what is actually a safety house?*
> Interviewee: *After the last fires in 2006 we joined the Community Fireguard Group here, which is all your neighbours, basically, in a group. And the [identity removed] came around with this and went to each person's house and assessed whether he thought it was safe or not … The one up there was safe because it didn't have any big trees around it. They had a generator to run their water pump, they had a fire hose, it's a brick house, they had sprinklers on the roof … [Identity removed] thought that [names removed] house was a safe house. But it wasn't a safe house. It was just number 1 on the fire tree because they were home all the time …* (Kinglake)

Analysis also revealed a number of 'community refuges' where residents believed they could shelter during bushfires. These included open areas such as sporting grounds, as well as commercial or community buildings including school classrooms, pubs, CFA sheds, wineries, hotels, bed and breakfasts and ski huts. The need for community refuges was most apparent in Marysville, where interviewees commonly identified the Gallipoli Park oval, the Marysville Golf Club and the Cumberland Hotel as places to shelter. However, there was some confusion over the 'designated' refuge point.

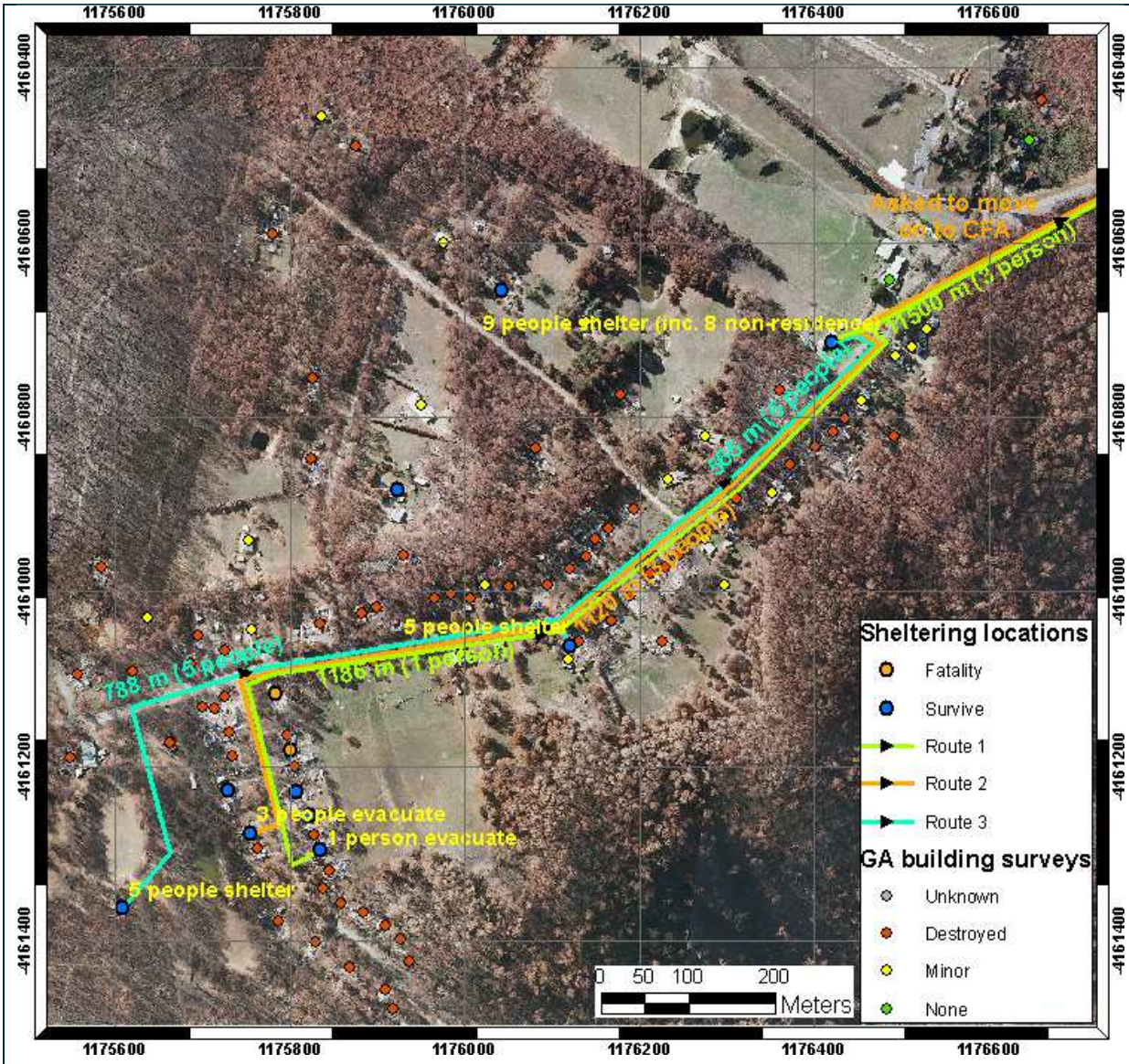
> *The footy oval is the safest place, it always has been. Plus you've got a little lake there too. If all else fails, you jump in the lake, pull a towel over your head or something.* (Marysville)

> *And then these four [nationality removed] tourists arrived and they came over to us and asked us what was going on and we said we weren't too sure but we might be in a bit of trouble and we sent them to the oval. The best place to go is, go to the oval.* (Marysville)

> *Two years ago my wife rung and asked the local council about where was a safe, what's the word for it, a refuge point. It used to be publicised years ago, it was the football grounds down here. Then it was changed to the golf club, I don't know whether you've seen it. Then the golf club for some reason objected, probably because of the stupid public risk fiascos. So there was no designated safe area in the town. People went to the football ground, yes, because that was all they knew. But there was nothing designated, nothing organised.* (Marysville)

> *This is another bit of confusion that's cropped up; about the last thing I knew about the evacuation point for anything like this was the golf course. And yet people finished up on Gallipoli Park … And as far as the Cumberland, that was never on the agenda as an evacuation point. So how that ever, you know, raised its head [I don't know].* (Marysville)

> *We all took shelter in a classroom that was furthest away from the fire which was coming from the west. We managed to get some tubs of water to try and fight some spot fires. We couldn't see the fire once we were in the classroom but we could hear it approaching. We were in the classroom for about 15 minutes.* (Kinglake)



Summary:

- Intention: Stay and defend
- Preparedness: Well prepared
- Summary: Five people from route three escaped a burning house to a second place of shelter and then a third place of shelter considered as a ‘safe house’
- House: First shelter destroyed, second shelter destroyed, last shelter house survived
- People: In total 12 people (survived)

Account from resident:

> *As all the back bedroom windows started to explode and the mattresses caught fire, I just ran around shutting bedroom doors. And [Resident] kept coming out trying to find us a clear path out of here. He knew that we had to get out of the house. You know, all I could think of was radiant heat, they tell you to stay with the house.*
>
> *In this situation, we - we had to get out, because the kitchen had burnt, which was on the other end of the house, all the back bedrooms. He came in a third - I think it was the third or the fourth time he'd been out, he came in and he said, "We go." … The only thing I could find was sheets in a hall cupboard, because all the blankets and everything were already on fire in the bedrooms. Dipped all the sheets in the buckets of water. Wrapped the kids up and said, "Run." … he couldn't get any further because the radiant heat - it was - like the fire was coming across here. So once you got to the edge of the garage there, you just couldn't go any further.*

And then he got to the point where he said, "Well, we have to go now." We hadn't [reach] that gate when we heard the rest of the house fall. So I reckon we were probably 20 seconds off. This one had an asthma attack mid-run down the road. So she was kind of half dragged, half carried.

We went to two other houses on the right-hand side down the road. As they burnt, we grabbed the kids and that house's occupants, and moved on to the next one. And [other person]'s place, the big brick one on the left-hand side, that's where we finally took refuge. She had a room underneath the house. Like - the house is built on an angle and there's a room - an almost a garage underneath. And so we put all the kids in there and all the animals. There were kids and dogs and cats everywhere. And we all went out to help [Resident] fight the fire. She's a CFA member. She was in full uniform. So we figured once we got there, we were pretty safe. And once all of us arrived - she was losing the fire at her place, but once all of us arrived and she had people manning hoses everywhere, her house was saved.

Figure 7 Case Study 2: Neighbourhood convergence on safe sheltering house.

The concept of a safe house or safe place in which people have confidence in reaching before a fire front arrives appears to be an inclination for many people. The examples provided are diverse in the level of safety provided. This infers an opportunity to formalise the criteria in which a locations of relative safety can be assessed along with the opportunity to identify and to design 'official' locations. The designation of neighbourhood safer places[12] and community fire refuges[25] are examples of these.

6.3 Beliefs about sheltering

Analysis of the interviews revealed a number of beliefs about sheltering that may have influenced people's behaviour during the bushfires. These included beliefs about fire behaviour and the safety of houses and bathrooms as places of shelter.

6.3.1 SAFETY OF HOUSES

While many interviewees believed that a house is a relatively safe place to shelter during a bushfire, others did not. Those who saw houses as safe places to shelter often recited fire agency advice to shelter inside a house during the main passage of the fire front, then go outside to continue defending. Many of these residents understood that the house might only provide temporary refuge from the fire and that it might be necessary to exit the house at some point. However, a small number of residents strongly believed that the house was the safest place to be and did not exit even when the house was burning (for example see Case Study 3 in Figure 8).

> *What I've always understood was you stay in the house until the fire front has passed and then if your house catches fire, by that time, you can get out, you'll have clear space to go and stand in …* (Steels Creek)

However, given their experiences of the 7 February bushfires, some interviewees questioned whether the advice to shelter inside houses was correct. They often referred to the extreme fire behaviour experienced on 7 February, believing that houses could not survive in such conditions. Interviewees who believed that houses do not provide a safe place to shelter often retold stories of houses that had apparently exploded during bushfires. These 'explosions' were thought to be caused by the build-up of extreme heat or as a result of pressure.

[25] http://www.cfa.vic.gov.au/plan-prepare/community-fire-refuges (accessed October 2015)

Interviewee 1: Everyone that I know that died got indoors … My understanding is, if you get the really big, gassed up hot fires your house will almost explode, the windows will go. Well, they can do if you get a real big fire come through. It can sort of suck the oxygen out of your house. Interviewee 2: Friends of ours lost their house. They had moved out, but the house actually exploded due to air pressure. (Mudgegonga)

It's just too savage. I mean, there is bluestone exploding and concrete cracking and bricks falling down. I even think if you'd had a bunker you would have had the air sucked out. I don't think there would have been anything anybody could have had that would have withstood this one. (Marysville)

I've been to CFA meetings over the years and they've said, 'Houses don't explode. It takes 18 minutes for a fire to … for a house to really get up and burning. So you've got 'this' amount of time to stay inside, the fire front or whatever. You've got time to get out.' Well, clearly that isn't the case. (Flowerdale)

I heard a story only just yesterday. I've spoke of a chap who – the fire had come through, broken through his house, blown doors off hinges. The fire had followed him down hallways, [in] its quest for oxygen. It blew two double doors off the rear of his house. Three cats bolted outside, and he reckons they made it eight feet – they combusted before his very eyes. (Strathewen)

One interviewee explained how he opened windows in his house during the bushfire to prevent the build-up of heat inside, which he claimed would have caused the house to explode. Official advice during bushfires is to close windows, doors and other openings to prevent the entry of embers.

I remember years ago someone told me, 'You've got to have at least a couple of windows open in your house', because what happens is the heat outside and the heat inside the house can't escape, so it actually gets hotter than what it is outside. Now I know that for a fact from my own experience. So I had this at the back of my mind and I opened the windows, couple of windows, and a couple of doors because I thought 'Well, stuff the smoke', and I know now in my own mind that if I hadn't done that, my house would have exploded from the inside out, because that's what happens. (Hazeldene)

These accounts and impressions identify the scope to further clarify the awareness and knowledge around house response to bushfires of varying intensity. These concepts and doctrines appear to require an increase in the complexity in which safety is discussed moving away from concepts of absolute safety to relative safety. In the various studies and follow up investigation of human accounts there is still no firm evidence that houses explode during the fire front arrival (e.g. Ramsey et al., 1987). However, some of the accounts detailed above highlight how rapidly a house can lose tenability if the window(s) are breached. This can occur when they experience very high levels of radiant heat, flame contact or intense wind events. If a house's exterior is extensively breached in this way fire can then rapidly spread through a house in minutes.

6.3.2 SAFETY OF BATHROOMS

Analysis of the interviews revealed that many people believed bathrooms to be the safest room in a house in which to shelter despite being the most common fatality location within a house (Blanchi et al., 2012; McArthur et al., 1967). The perceived safety of the bathroom appears to stem from the ready availability of water, particularly in the bathtub, and the hard surface contained nature of the room. It is noteworthy that children and pets were often confined to bathrooms, with and without the presence of adults.

I went into the bathroom with the boys, obviously the smallest place, safest place in the house. I filled up the bath. That was all filled ready to go. We just stayed in there. We had blankets, water,

torches. [Names removed] stayed outside until the fire hit, and then they came into the bathroom and then they went out and started putting out spot fires. (Castella)

We had the kids in the bathroom, had all the windows sealed with wet towels around the house. Filled the bath, because that's where the children were going to stay, in the bathroom, with the dogs. (Kinglake West)

My wife was inside most of the time, and he [four-year-old son] was told to stay in this room, in the bathroom, which was the designated safe room. And he had a couple of toys and books. (Kinglake West)

The house is chocker block full of smoke and I didn't know whether I should leave or whether I should stay there. So I just stayed there in the end and someone told me to go into the bathroom, so I just went in there. They reckoned it was the coolest place and [I] just chucked the exhaust fan on, because it's so smoky in the house you couldn't breathe. (Horsham)

An interviewee who was a member of a local CFA brigade and who participated in the search for survivors after the bushfires mistakenly believed that it was official policy for people to shelter in bathrooms:

[My son] came up the drive and he came in and he's 'Dad, Dad, Dad, we found [deceased] and [deceased].' They were in the bathroom exactly as per the CFA guidelines. Probably filled the bath, well, they may not have filled the bath because there wasn't any bloody water, and she wouldn't have, she wouldn't had time to fill it, I don't think, before the water stopped. They were in the bathroom which has had only one small external window which she would not have been able to get out of, and you know, it was in the back of the house and so the whole house would have been on fire … Why? Because they were all in the bloody bathroom and the bloody bathroom hasn't got an external door, the bloody bathroom hasn't got a big enough window to get out of … (Marysville)

Despite widespread beliefs about the relative safety of the bathroom as a place of shelter, many interviewees were aware of the dangers of sheltering in a room with limited egress and limited visibility of the fire outside.

6.4 Summary

People sought shelter in a range of locations and shelter types, mainly inside houses, inside commercial buildings such as hotels, pubs, wineries and ski huts. A large number of residents and fire personnel sheltered in and around CFA sheds. In some cases, people sheltered in sheds, bunkers or open spaces such as sports ovals or paddocks; alternatively, they found protection in pools, dams or rivers. Some shelters failed and people had to seek alternative shelter to a maximum of three shelter locations.

The research identified a number of beliefs regarding safe houses' that residents had planned to shelter in during a bushfire. Some people also believed bathrooms to be the safest room in which to shelter. Indeed, it was the most used room by people sheltering inside houses.

7 Activity and challenges during sheltering

The first section of this chapter discusses the activities of resident while sheltering and includes the factors leading to sheltering, the distinction between active and inactive sheltering, monitoring of the fire activities, actions people took to protect shelter and occupant and group shelter. The second section highlights the main challenges and health issues people have experienced while sheltering.

7.1 Factors leading to sheltering or not

People discussed the fact that they had sheltered because it was too late to leave. Ideally, they would have liked to evacuate but considered that the roads would be dangerous. Some had attempted to evacuate but returned home because they found the roads blocked by trees, traffic or fire. Others found that they could not evacuate from their properties because the fire had already arrived.

> *We couldn't get out. There were eight cars on the road and no-one knew where to go. So we spun around, came back in the driveway.* (Kinglake)

> *I just put me boots on and ran back upstairs expecting to get in the truck and piss off … I came to the front door to get out this way. Opened it up and my truck was on fire. The tree was on fire. There was just flames everywhere.* (Christmas Hills)

> *We had to run back inside because we knew, we couldn't even make it from here to there. It was pitch black ... In that time period, when we went back to open the door, it had hit. Pitch black outside. Sparks. You could feel the radiant heat. And knew we just couldn't go.* (St Andrews)

People also stopped to shelter where they saw others sheltering or where they had been advised by others to go. In a few cases, people said they had planned to shelter somewhere but did not because when they arrived, no one else was there so they moved on. One couple were told to shelter at the Cumberland Hotel in Marysville but on arrival could not see anyone and therefore drove on.

> *The lass from the DSE [Department of Sustainability and Environment] here saw us in the driveway and came out and said, you know ... you've got to evacuate to Cumberland. Of course at that point I thought well with the communication that she's got in there she must know something more than what I know from the radio reports and everything else.* (Marysville)

For those who planned to shelter, or to travel to a predetermined local sheltering location, the most common trigger was seeing embers, flames, heavy smoke, darkness, wind and, in a few cases, noise. For those who were defending, the arrival of the fire front, the force of the radiant heat and flames were the dominant triggers that led people to retreat inside a structure or to move behind a physical barrier such as a pillar. Some participants discussed injuries sustained during defence, which led to permanent or temporary sheltering and also physical exhaustion, overheating and the need to rest. Others stated that it was the level of smoke and darkness that led to problems breathing, and not being able to see, which motivated them to seek shelter. A few also discussed the sound and the force of the wind and their fear of being knocked over or hit by debris. Problems with equipment failure, such as loss of water pressure and loss of power, were also a factor leading to sheltering. Participants also returned inside to seek food and water, to monitor the passage of the fire and to network with friends and family over the phone.

> *I was outside in it for a couple of minutes, and I got – it peeled the skin off me everywhere. Hair caught on – that's why I've got no hair. Hair caught on fire. Back of my arms. My hands.* (Callignee)

> *The radiant heat from that shed is starting up and the firewood pile was too much and we both sort of said at the same time, 'That's it, we have got to go inside.'* (Kinglake)

There was one time that I got hit by a wall of smoke over there, not flames, but a wall of smoke. It just about knocked me over, and I dropped the hose and came in behind the machinery shed before I could recover. I didn't have a mask on. (Yarra Glen)

And it was just – like a tornado came through. And couldn't breathe; couldn't see, couldn't – you know, the stuff was falling out of the sky. So I came inside. (Traralgon South)

They came in quite a lot. I mean, I had drinks and all that, and there was lots of phone calls. And there was quite a bit of networking with friends around the area. (Traralgon South)

I expected the power to go off eventually and I was just hoping I had more time. Once it went off, then we just sought refuge in the car. (Kinglake West)

[Resident] had taken refuge under the carport and when I reached the veranda he came to join me. It was intensely hot, probably between 300–400 degrees radiant heat, and we decided that our last stand would be in the house, trying to protect that. (Callignee)

When the fire got to within 20 metres of our house, it was too hot to stay outdoors. We went inside to protect ourselves from the radiant heat. At this stage the embers were flying around our house horizontally and there was smoke everywhere. (Callignee)

A number of participants discussed how their sheltering behaviours were influenced by vulnerable people in their care, typically the elderly, young and those with disabilities. This also included guests and visitors who were new and unfamiliar with the area, and also pets. Often this involved keeping these people comfortable and calm while monitoring the inside of the house. One interviewee described assisting his 95-year-old uncle to shelter inside the house and then move outside as the house burnt down. Other examples included mothers looking after their young children. Chronic breathing challenges such as asthma and emphysema were noted as a particular problem for those sheltering and for one interviewee, this led to him moving his parents-in-law from one sheltering location to another to escape smoke. One interviewee noted how she had been forced to shelter inside due to breaking her leg 10 days prior to the fire.

[Wife] was inside the house with the guest that we had, who was pretty freaked out, so she needed to, you know, sort of nurture her ... (Steels Creek)

And then it just, night-time came, you know, it just went all dark and that's when we knew it was coming up this way. I put the kids in the bath. She was inside looking after the kids, and I just ran around, you know, putting the spot fires out. (Kinglake)

My wife's parents were there and they're in their late 70s and my father-in-law's got emphysema and they were struggling to breathe in there. So that's when we decided we're out of here … so we made a bolt to Kinglake and that's where we spent the night at Kinglake in the fire shed with probably 200 hundred other people. (Kinglake)

Respondents discussed reasons why they had sheltered in some locations. With respect to other people's properties, it was because the building and location were considered safer than where they were and/or the home owners were thought to be well prepared and skilled (see also Section 6.2 on safe houses).

We went to a safe house … Well it's a friend of ours. She's in the CFA … Yeah she was all set up … she had diesel generators and pumps, she had water, alternate electricity supply and she had garbage cans around the house with mops in it full of water. (Kinglake)

The one up there was safe because it didn't have any big trees around it. They had a generator to run their water pump, they had a fire hose, it's a brick house, they had sprinklers on the roof. (Kinglake)

The destruction or untenability of people's houses led those who had been defending their house to seek shelter and those who had been sheltering inside to seek alternative shelter. One family sheltered in their house because they considered it too dangerous to walk to their bunker. However, when the house caught fire and the smoke became too noxious they decided to evacuate to their bunker. Similarly, another family discussed how two men defended the house and two women sheltered in it. When the house caught fire and it became too difficult to breath inside they all sheltered outside behind the water tank. One family described how they abandoned their house when it caught fire only to shelter at two other houses that also caught fire before finding a house that was defended and saved.

> *We stayed in there until literally the – the roof was caving in on us. And then we made a run into and through the fire between our back door and our concrete water tank. So we made the run to the water tank. And that's where we survived basically.* (Callignee)

Another important factor that influenced sheltering was whether people could take pets with them. One respondent discussed how they were told that they could take pets to the town hall and only then decided to shelter at the town hall. The comfort of the sheltering locations was also a factor and some respondents noted that some mass shelters were hot and overcrowded, prompting them to move location.

> *Eventually, someone came and said, 'They're opening the town hall, you're welcome to take animals in there.' So we went down there. There just wasn't enough room in there, and it was just so hot and stuffy. We were probably only there less than an hour, and they said, 'Go to the footy oval. They've opened that up.'* (Kinglake)

Not sheltering

One interviewee discussed how they had a bunker and had intended to shelter but when they saw the approaching fire front they panicked and evacuated in their car.

> *I started me pumps and was going to go down and hop in my fire bunker and seen what was coming over the hill and thought 'No way' and I got in the car and I left, which is probably a silly move. I couldn't see the road for smoke ... The ferocity of that fire, I've never seen nothing like it.* (Hazelwood South)

7.2 Activity during sheltering

7.2.1 ACTIVE VERSUS INACTIVE SHELTERING

A broad distinction can be drawn between active and inactive sheltering. Active sheltering is characterised by regular monitoring of the fire and conditions inside and outside the place of shelter, as well as actions taken to protect occupants. Such actions include extinguishing fires; preventing the entry of smoke; and caring for children, the elderly and people who may have been injured. Inactive sheltering is characterised by a lack of regular monitoring and actions to protect occupants. Evidence suggests that the majority of residents who sheltered engaged in monitoring and activity to protect occupants. However, there were households where one or more people sheltered inactively, often children and the elderly, while others defended or actively sheltered. Cases of inactive sheltering were more common among those who had bunkers, and those who found themselves sheltering unexpectedly (Case Study 3 in Figure 8), such as those who were forced to shelter outside while defending.

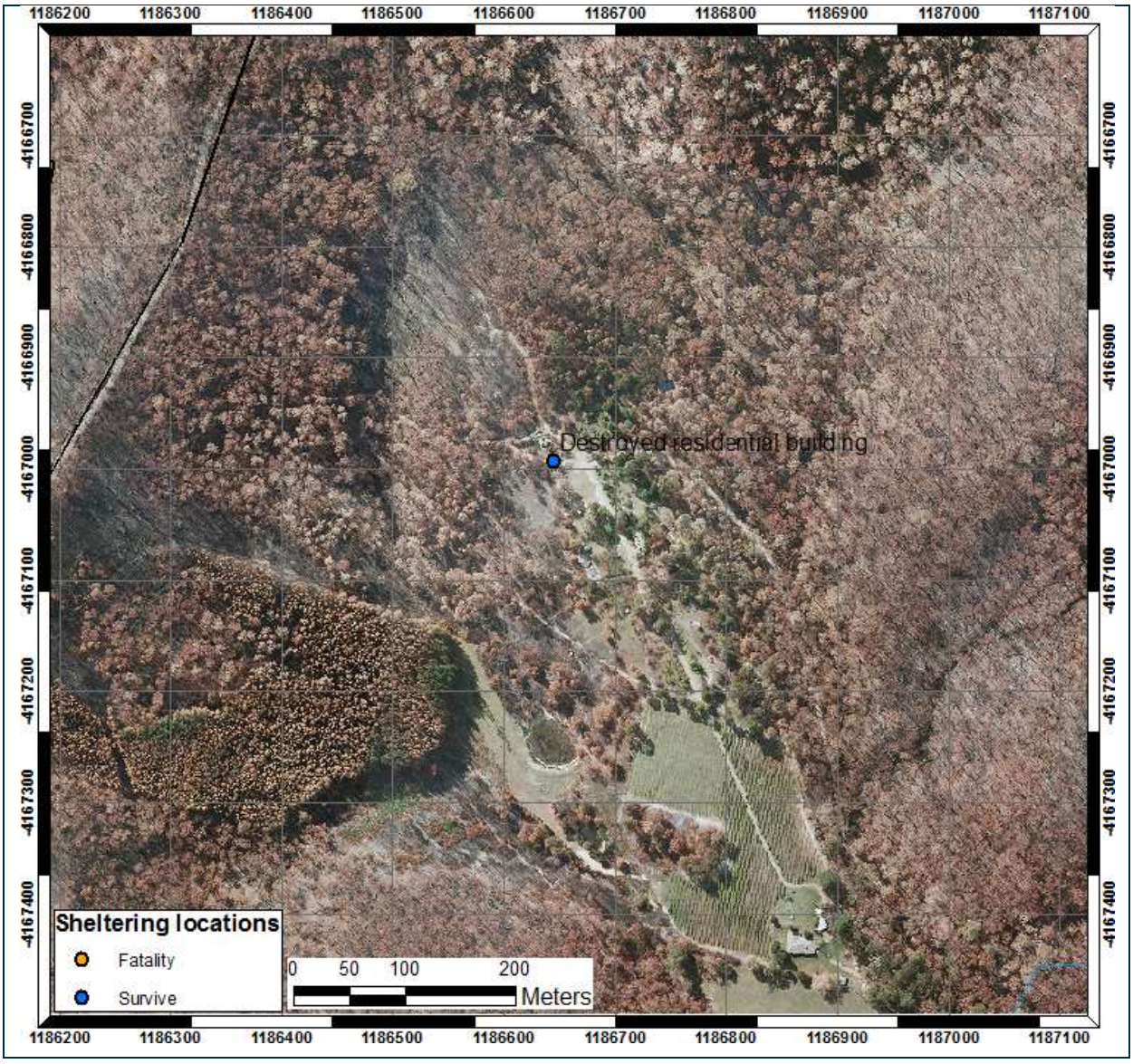
From the perspective of the total number of fatalities and survivals, 31% of fatalities were people who actively sheltered, while 58% of survivors were people who actively sheltered. If we look at the roles of people, 90% of those who actively sheltered survived while 74% of those who were inactive while sheltering survived (See Table 9 and Table 10). However, many inactive people had someone being active with them. There were only 22 cases out of 325 incidents where all members of the household sheltered inactively.

Table 9 The number of people with active, inactive and unknown behaviour categorised by their survival (frequency and percentage of total for each row).

Survival	Number of active people	Number of inactive people	Number of people with unknown behaviour	Total number of people sheltering
Fatality	52 (31%)	71 (42%)	46 (27%)	169 (100%)
Survive	482 (58%)	202 (24%)	154 (18%)	838 (100%)
Total	534 (53%)	273 (27%)	200 (20%)	1007 (100%)

Table 10 The number of people with active, inactive and unknown behaviour categorised by their survival (frequency and percentage of total for each column).

Survival	% of active people	% of inactive people	% of people with unknown behaviour	% of the total number of people sheltering
Fatality	52 (10%)	71 (26%)	46 (23%)	169 (17%)
Survive	482 (90%)	202 (74%)	154 (77%)	838 (83%)
Total	534 (100%)	273 (100%)	200 (100%)	1007 (100%)



Summary:

- Intention: Stay and defend
- Preparedness: Unknown
- Summary: Husband outside defending, wife stayed inside with guest, strongly believing that staying inside is the safest option, the house started to fill with smoke and it became difficult to breathe and they started to 'go under', guest convinced resident to get out, it was better outside as the fire had passed.
- House: Destroyed
- People: 3 people (2 sheltering)

Account from resident:

> *I stayed in the house with the young woman who was with us and truly believing I was in a safe space. But what happened was the house filled of smoke and it got darker and darker and darker until it was totally pitch black, and I'm totally still believing the safest place is to stay in the house, and outside I knew there were flames, so from my preparation, … I was going to stay inside that house and I'd have gone with the smoke because we were starting to pass out, and she [guest resident] fortunately rushed out and said, 'No, come out here. It's perfectly safe.'*
>
> *So since then I've heard that if your house smelt of smoke, it means the fire's passed over and it's safe to go outside. I had never heard that. Never heard that. I didn't even think that was an option. You know, I'm presuming that many people may well have died by doing that because I certainly would have … and this smoke was getting really easy, like it was like an anaesthetic. It was just like I was starting to really start going under, so it was an obvious choice. So she saved my life by going out then, and it was clear. It was so safe out there, and that was the slab that we cleared of all the trees out that side, and it had all burnt.* (Steels Creek)

Figure 8 Case Study 3: Example of inactive behaviour.

7.2.2 MONITORING

The vast majority of residents engaged in monitoring while they sheltered. Most people regularly monitored the progress of the fire and the immediate surrounds of their house by looking out of windows. Some interviewees described how they regularly 'patrolled' the exterior of their house to check for ignitions. Many also monitored the interior of their house, including roof spaces, for signs of fire. Other reasons for monitoring included checking on the safety and wellbeing of people who were outside defending, and assessing when it was safe to exit the house or shelter. Prior preparation was important in enabling people to monitor effectively. Many residents brought ladders inside to provide access to roof spaces, while others had appropriate clothing and personal protective equipment to allow them to monitor outside safely. Some interviewees reflected on their lack of preparation, which inhibited their capacity to effectively monitor while they sheltered.

> *We had the ladder propped up in the manhole. All I had to do was to go up and stand at the top of the ladder, keeping watch on what was happening inside the roof, in case any sparks came in. They didn't but I would have been ready for them. I must say, the mining lamps were invaluable. They allowed us an excellent source of light … From time to time I came down and helped [my wife] in the task of patrolling from room to room, looking through the curtains.* (Marysville)
>
> *I was in the house and [my husband] was sort of collapsed on the couch [with smoke inhalation and burns] and saying 'I can't do anything.' And I said 'Yes you can, you can just stay there and tell me if you see or hear a window break, or if you see smoke get under a door, just tell me where it is and we'll deal with it.'* (St Andrews)

We were checking – kept running upstairs, downstairs, seeing what was burning in the house, and what was burning on the balcony. We could see that the balcony decking was catching on fire, so we'd have to go outside and throw a bucket of water on the hot spot and run back inside. But yeah – just constantly checking every room. (Strathewen)

As noted above, monitoring was also critical for assessing when it was safe for occupants to leave their place of shelter. Most people were able to recognise when the fire had died down and it was safe to go outside. There were a few instances where residents were not monitoring the fire and remained inside houses that filled with smoke. The presence of others who were monitoring most likely saved their lives. For example, one interviewee explained how her fear of fire rendered her impassive during the bushfire. She was fortunate that her houseguest went outside to see if the fire had passed. Another interviewee described being overcome by smoke and anxiety and lying on the floor inside a building. An onlooker alerted her to the fact that the building had caught fire.

The house filled with smoke and it got darker and darker and darker until it was totally pitch black. And I'm totally still believing the safest place is to stay in the house. And outside I knew there were flames, so from my preparation, and we were mindful of all the knowledge I'd gained along the way, I was going to stay inside that house. I'd have gone [died] with the smoke, because we were starting to pass out, and she [a guest] fortunately rushed out and said, 'No, come out here. It's perfectly safe.' So since then I've heard that if your house smelt of smoke, it means the fire's passed over and it's safe to go outside. I had never heard that ... I didn't even think that was an option. You know, I'm presuming that many people may well have died by doing that, because I certainly would have … At that point in time it [going outside to monitor] was just to see where I was going to die, and I would burn, that would be just awful, it would be pain. And this smoke was getting really easy, like it was like an anaesthetic. It was just like I was starting to really start going under ... So she saved my life by going out then. And it was clear – it was so safe out there. (Steels Creek)

I had to lie down on the floor … I had smoke inhalation and a bit of anxiety to boot. I lay down on the floor with a wet rag over my face. One of the other guys was vomiting because the smoke was that bad. Two of the people stayed out on the oval because he'd just got out of hospital with a hip operation and he was sitting in his car and he yelled to us to get out: 'You're on fire!' The building was on fire. (Kinglake)

The capacity to monitor what was happening outside was limited for those who sheltered in bunkers, cellars or other such structures. In many cases, these people monitored the fire from inside or outside a house and moved into the bunker or cellar as a contingency.

And we sat in there. I put the wet towel across the bottom of the door and started praying and we just listened to the place just explode. There was just, I don't know, houses, cars, gas tanks, whatever just blowing up and apart from the sparks coming into the bunker through the door – it nearly got through the door in the bottom right-hand corner I think, or something. It was like it was hunting you, you know. Anyway, we were in the bunker for about maybe 20, 30 minutes. (Kinglake)

Once the main fire front passed, residents sought shelter inside houses, cars and other structures that had survived. Many remained vigilant throughout the night, often taking turns to patrol the house to check for ignitions.

7.2.3 ACTIONS TO PROTECT SHELTER AND OCCUPANTS

The vast majority of interviewees described taking at least some action to protect their shelter and its occupants. It was also common for people to shelter in houses or other structures that were being actively defended by others. The most common action taken by those who were sheltering was to fill baths, sinks,

buckets and other containers with water (some residents did this in preparation for the fires, others in response). Some residents proactively wet down internal and external walls, doors and windows. Most people wet towels or blankets to seal doors and reduce smoke entry. As houses began to fill with smoke, some residents lay on the floor or knelt over the bath with wet towels or blankets over their heads.

> *When the actual fire front hit, we were in the bathroom … We just had the bath half full of water, and we just stayed in there … just kneeling down over the bath with a wet towel over our head, breathing through the wet towel … When I got up to move round to check other rooms, I just had a wet handkerchief tied around my mouth.* (Callignee)

> *The smoke got really, really bad … I had wet towels and we put them over our head and put our faces to the carpet where you could breathe a little bit easier … [My friend] kept spying out the doors and looking, and all he could see was embers coming everywhere … I was looking out the back windows. Like I said, I had every blind open so we could see what was going on.* (Kinglake)

Regular monitoring meant that people were able to detect ignitions on, in and around the house, which they may then have attempted to extinguish. In some cases, early detection meant that fires were extinguished relatively easily. However, there were cases where undetected fires took hold or where residents were unable to safely go outside to extinguish fires. While some people exited immediately, others tried to wait until the fire outside had subsided. A number of interviewees described moving progressively through the house and exiting at the last moment.

> *I went back downstairs to the laundry to try to get out that way. I opened the door and flames came in. And I shut the door and just stayed in the laundry, as long as – I thought I had to stay in the laundry as long as I possibly can and hopefully the fire will go over me and piss off somewhere else. And I kept looking out and it was just flames everywhere. Looking out the other door and by now the lounge room downstairs was on fire. And I was surrounded in flames. And I could hear the windows smashing and the top of the house coming down. And I just waited and waited and waited until the laundry started filling up with smoke. And then I saw flames on the ceiling and I knew I had to get out … And then I opened the door; nothing but flames. And I ran into the flames and hopped and skipped and bounced my way to the bottom of the driveway. And as soon as my feet hit the ground I heard this smashing and crashing and I looked around and the whole house was coming down within less than 10 seconds of me leaving it.* (Christmas Hills)

> *[The fire] got me from the back of the house. And once it had caught, I was blocking off room by room in order to stay in long enough for the fire front to go through. Because I knew the south-westerly [wind change] was due. It was so due, so close to coming through. And at one point the house started to fill with smoke … And I realised at that point that if I didn't get out of the house I was going to die … So I grabbed my mobile, I grabbed my handbag, I tried to grab my files but they fell and burst open. And I grabbed the one dog that was near the door and I tried to get the others out and I couldn't, they wouldn't come … My car was untouched. And I took a punt.* (St Andrews)

Looking after children was a key task for many people while sheltering. Interviewees often described how they kept children calm by keeping them away from windows so they could not see the fire. Others kept children occupied by giving them simple tasks such as wetting towels and placing them around the house. One interviewee explained that she made the children hold hands so they were not separated in the dark house.

> *My grandchildren came inside with me, and we filled up all the sinks and the baths. And I had two old pure woollen blankets, which we soaked in the bath. I got the little ones – the two-year-old and the seven-year-old – we sat them on the tiles in the middle of the kitchen floor … My seven-year-old granddaughter – she was at the sink wetting all the towels for me. I kept her busy. She ran around*

and we put wet towels on the inside around all the doors, the gaps under the doors and things. (St Andrews)

The importance of looking after children or other dependents was emphasised by Whittaker et al. (2013). The results of the household mail survey, after the 2009 bushfires, revealed that half of the respondents had to look after dependants including infants or children, elderly persons or disabled persons (see Table 11).

Table 11 Members of the household who needed looking after during the fire (extracted from Whittaker et al., 2013).

Survey categories (categories of people requiring looking after)	Frequency	Percentage
Infants or children	262	23.7
Elderly person/s	45	4.1
Disabled person/s	26	2.4
Ill person/s	21	1.9
Other able-bodied adults who became ill or stressed during the fire	56	5.1
Other	65	5.9
No	523	47.4

Many people found the experience of sheltering with children extremely challenging. The presence of infants and very small children meant that some adults were unable to assist in defence of the house, or regularly monitor what was happening inside and outside. Many residents sheltered in bathrooms, darkened rooms or other confined spaces in the house. These spaces provided immediate protection from the fire outside, but often provided limited visibility or access in the event that occupants needed to exit the house. A very small number of interviewees left children unsupervised in these spaces, often with pets, and checked on them periodically (see Section 6.1.3).

The house is built on an angle and there's a room, almost a garage, underneath. And so we put all the kids in there, and all the animals. There were kids and dogs and cats everywhere. And we all went out to help fight the fire. (Kinglake)

And we had a two-year-old baby in here too that was freaking out. We had a fabulous time with him messing everything up. So we had to come in, so what we did was we shut all the doors because smoke and everything was coming from that direction … I got all the ice and stuff out of the fridge, put it on the floor, put the baby there. (Pheasant Creek)

[My daughter's] head, even though I had her in a woollen outfit, wet in the bath, her head was beaming [sic], it was boiling. And I just kept wetting her down and getting her to suck on a wet face washer. And [my son], he did really well for the first 24 hours and then he deteriorated with the smoke in the air. He had an asthma attack in hospital the next day. So we were very lucky. (Kinglake)

[Female residents] put out the larger spot fires while taking turns to run inside to calm the kids and bringing us drinking water and wetted down towels. (Kinglake)

Some residents found themselves caring for people who were injured in the fires. These included people with major and minor burns, smoke inhalation and other injuries. Those who had to care for the injured also found themselves diverted from intended tasks such as defending the house and actively sheltering.

Some residents played important roles in providing first aid and assisting people who were incapacitated, as well as caring for people who were traumatised by their experience.

> *We had the next door neighbours in, the people from across the road. So once they were in there, that's all we were doing … They were fully aware that [people in the house] were dead and I thought I didn't know anyone in that house so I managed to be able to just not worry about it and just keep going. While I knew it was devastating, [name removed] was screaming a lot so I had to try and distract [gender removed] all the time to keep [gender removed] calm because I was worried about everybody else freaking out. And [name removed], I think [gender removed] is like [age removed]. [Gender removed] was just wanting to get out and run and so we had to try and keep [gender removed] from going hysterical and running outside ... So, you know, [gender removed] was aware that [relatives] in the house had died ... So yes, they were all fully aware of what was happening so you couldn't leave them for a second, and [name removed] wasn't breathing well so we had to keep [gender removed] breathing and we had to keep everyone's liquids up and we just sort of had to sit them around. We just had to sit them, you know, like – and not let them move and – you know, like they were full-on. Like they had to be looked after constantly, so [name removed] and I, that's all we did, was run around after them.* (Location withheld)

7.2.4 GROUP SHELTER

There are examples of group, including many people and pets, sheltering in residential and commercial buildings. The Table 12 presents the total number of people sheltering at one place for each incident. Most of the incidents involved one person (*n*=90) or two persons (*n*=107). However, 28 incidents have involved six persons or more, with a maximum of 26 people sheltering inside a residential building, more than 30 people sheltered in commercial buildings. Statistical analysis of the data showed that the number of people actively sheltering had the strongest influence on the probability of surviving in a sheltering location (see statistical analysis in Section 8.3). However, there was a case where nine people sheltered at someone else's house and perished.

> *Because I was confident that my house would be safe, I invited [name removed], [name removed] and the family into my house – they all went upstairs to the living area where the curtains were shut so the children could not see the fire. I hoped that everyone would calm down when they were upstairs and I also wanted them out of the way. At around the same time, my friend [name removed] arrived at my house in his car. [name removed] is [age removed] and he had driven to my house from his house in, [location removed], which is to the south-west of Kinglake West. [name removed] said that he was literally chased out of day and he said that he thought he would be safer at my house when the fire front struck. [name removed] was the last person to come to my house for shelter and in total, there were nine of us.* (Kinglake West)

Table 12 Frequency of people sheltering at one location for each incident (regardless of the number of shelter used).

Number of people sheltering	Number of incidents
1	90
2	107
3	44
4	35
5	21
6	5
7	8
8	3
9	1
10	3
11	1
13	1
16	1
19	1
26	1
30*	1
35*	1
50*	1
Total	325

*Commercial buildings

7.3 Challenges experienced while sheltering

Residents were faced with many challenges such as noise, falling objects, burning elements a lack of visibility, while sheltering, going to a place of shelter or exiting a shelter.

7.3.1 LACK OF VISIBILITY

Many residents were surprised by the lack of visibility when the fire arrived. They described that suddenly everything went dark. This is mainly due to the size of a convection column obscuring the sun and forming a temporary barrier to the wind. The formation of a convection column on Black Saturday is not spatially consistent across the landscape, hence it may appear in some occupants' accounts and not others. Most people also complained about the lack of visibility outside and inside the house because of the smoke.

> *I think other people here have described it as the world turning black and orange, which is a very accurate description. It went very dark outside and the embers were being driven by a very, very strong wind, far stronger than it had been earlier in the day, and they were being driven horizontally against that side of the house, the western end of the house and they were coming in every tiny crack.* (St Andrews)

> *At one point, I was only about 50 metres from the house putting out a spot fire and I could not see where the house was. That really frightened me – I didn't want to be outside in the dark with the fire coming. Fortunately, I could see some solar lights along the edge of the path and I used these to get back into the house, where I sheltered.* (Callignee)

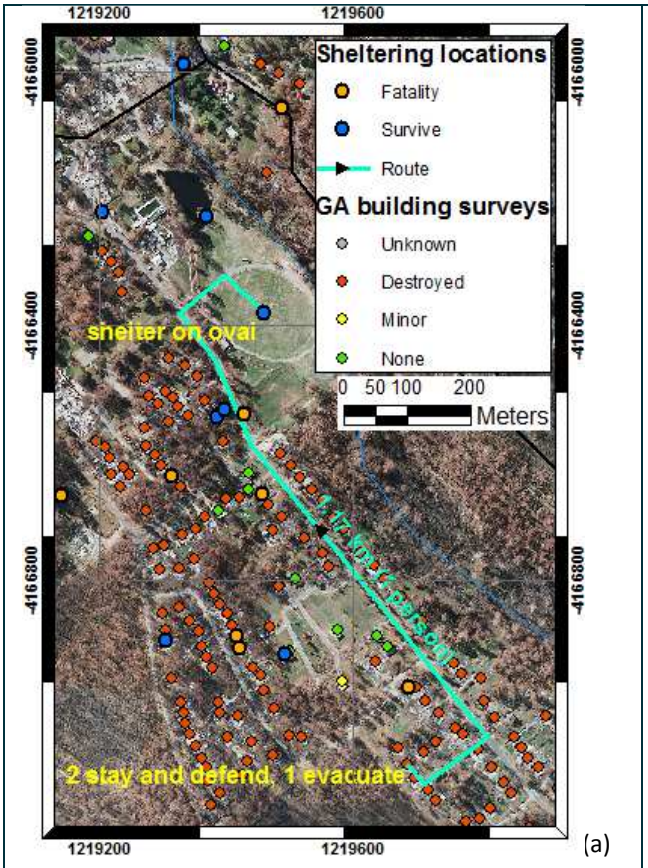
> I didn’t know really where I was because it was pitch, and it was just so incredibly ferocious, but I found a wall of [name removed] house and so I just crouched down and sat through it. I had to. I had nowhere to go. I had nowhere to go. I didn’t – you couldn't get your bearings 12 other than when I found that wall and [resident] said to me ‘You should have gone inside’, but I couldn't go inside because I couldn't find – I didn't know where I was. You know, I couldn't have possible got inside. (Clonbinane)

> *Embers were terrible could not find my way to Gallipolli Park because of the smoke haze, embers, trees falling.* (Marysville)

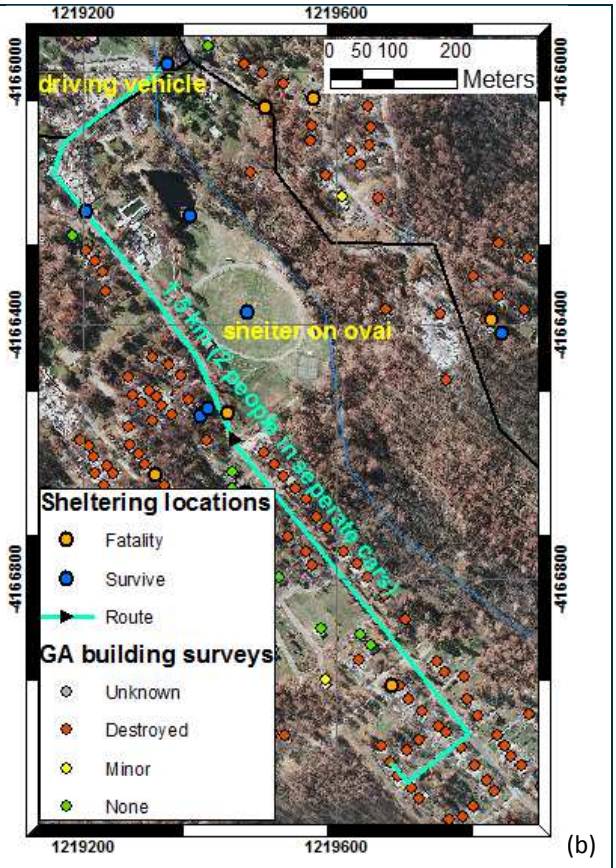
Some who evacuated in vehicles and found the roads blocked, or were involved in accidents, were forced to find emergency sheltering locations in others’ houses, public structures, physical barriers or on open ground. For many of these people, sheltering was not a pre-planned activity but a desperate last minute action to save their lives. People chose the safest locations that they could and some moved around when their current location became untenable.

> *I got stuck on a log or a piece of branch that had fallen out of a tree and it disabled my ute, so I was stuck … I knew the lay of the land so I thought, ‘Well, I'll go to the biggest open space that I know there and take it from there.’* (Callignee)

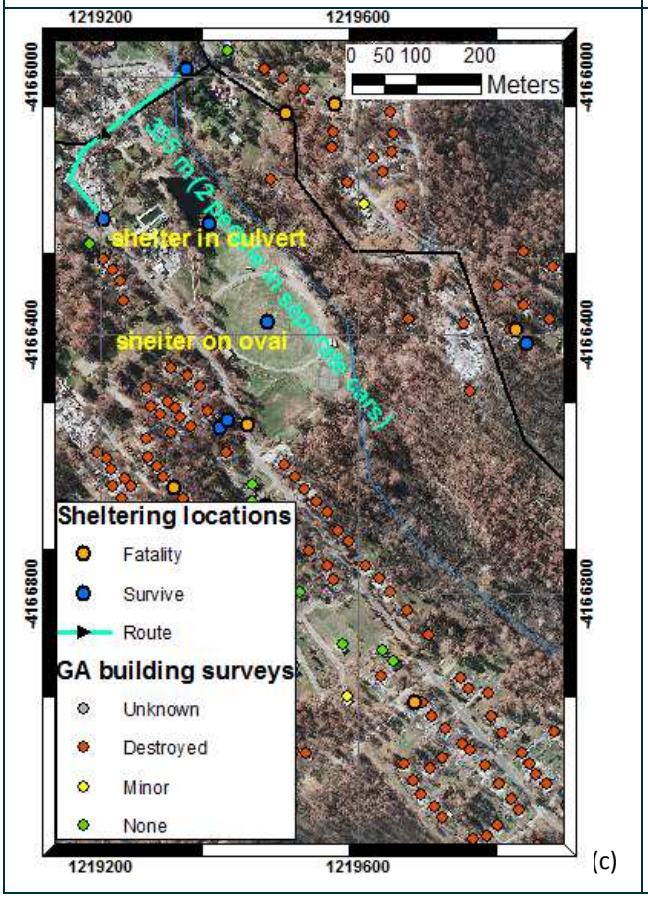
Being able to find intended sheltering locations was noted as a challenge by some interviewees, leading them to shelter in locations other than that which they had intended. People faced many challenges while travelling to a shelter (see Case Study 4 in Figure 9).



(a)



(b)



(c)

Summary:

- Intention: No fire plan, 2 stay and defend, 1 evacuate
- Preparedness: Unknown
- Summary: Husband and daughter stayed to defend, wife left to Gallipoli oval (a). Wife sheltered in car with others on oval. Husband and daughter tried to defend but unable to, so left during the fire for the oval (b). Could not get to the oval (describe lack of visibility) and ended up sheltering in a culvert (c).
- House: Destroyed
- People: 3 (survived)

Account from resident:

Planning to defend. But [resident female] was getting nervous about staying so she brought the car up the driveway up the lane and positioned. [Resident female] met [other resident female] at the front gate and I said, please come with me. She said mum I can't leave dad. So I [resident female] got in the car and I drove down the road. The road was clear. So I just turned into the oval and that's where I parked just inside the gate and I followed [name removed] into that area, parked just inside the gate.

[resident male and female stayed at the house]. I met my daughter coming up. She said we've got to go. I said to her, you get in your car and I will get in one of mine and I'll meet you at the front and she went the other way. … So I went down, hit Falls Road, I mean visibility was almost zero and I could see her lights and I pulled onto the road and drove straight into the gutter. … So we had actually come down past the fire front. The fire front had gone through and lit up all the houses and then we were going through after the fire … Next thing we were at the school. So I've missed the entrance to the oval because of the glare and disorientation and lack of visibility … a manna gum across the road, a huge manna gum across the road, blocking the road. So I stopped, jumped out of my car … and I said we've got to get back to the oval, the road's blocked. … So by the time I caught her she had actually gone past the entrance into the oval beside the kindergarten. She was almost up at the police station. … I said look, we're going to have to leave the cars here. … What we'll do is grab the dogs. We will walk around the bottom of the dam, the lower edge of the dam, between the dam and the river and onto the oval and we'll be fine ... She said what about the dam, I said no we'll go to the culvert … Now I'm very in favour of the culvert as a fire refuge … So we went to the culvert and we swim into the culvert with the dogs. (Marysville)

Figure 9 Case Study 4: Example of sheltering issues due to lack of visibility.

7.3.2 NOISES

Many residents mentioned the noise generated by the fire as being extremely loud and distressing. Smoke alarms were another source of noise and created additional stress for some residents. Residents also mentioned hearing objects exploding.

> *Once inside, the fire front sounded like a hurricane. Burning embers slapped into our windows and the rest of the house. I recall saying at the time that it was like being inside a washing machine on spin cycle and full of fire and embers. In addition, and despite my wife's efforts, the house filled with smoke almost instantly.* (Steels Creek)
>
> *A window had cracked and the fire had got into the western end of the house. The smoke alarms were going off (5 metres up on the high ceilings) and driving us mad.* (St Andrews)
>
> *Our smoke alarms were going off so I knocked one of them off the ceiling with one swipe and threw it into the refrigerator so we could at least hear ourselves think. I was also concerned about the impact that the noise was having on [name removed], whose Autism means that he is very sensitive to sound.* (Kinglake)
>
> *I also heard cars exploding at about this time. [name removed] was distressed and said that she was having difficulty breathing.* (St Andrews)

7.3.3 COMBUSTIBLE ELEMENTS

Residents were exposed to the combustion of surrounding elements (see Figure 10). In some cases, these elements were used by residents as a barrier from the effects of the fire but when ignited became a source of flame, radiation, smoke and/or embers. There is a wide diversity of combustible elements in an urban interface, ranging from heavy and fine vegetation fuels through to complex combustible man-made heavy fuel objects that form structures. Findings from post-bushfire surveys have highlighted the potential risks posed by immediate objects surrounding a house (such as fences, adjacent houses, outbuildings, ground cover, vegetation, vehicles and rubbish bins) in increasing the risk of fire spread in urban areas (Leonard et

al., 2003; Ramsay McArthur, N.A. Dowling, V.P., 1987). Wilson and Ferguson (1984) identified the influence of garden vegetation in the windward direction on house damage and destruction during the 1983 Mt Macedon fire. They also determined that 40% of houses in their study area were affected by one or more nearby burning objects (e.g. garden sheds, wood heaps).

> *After about 10 minutes, however, we noticed that our house was badly ablaze … I then went back inside the house but [name removed] and [name removed] had already gone outside. They were sheltering behind a car. By this stage the fire front itself had passed but our house and several parts of our property were on fire. We decided together that the safest thing to do was to move our cars to a clear area and shelter inside it … I then moved my car away from the house and to a clear and flat part of our driveway. We then sat inside the car and watched our house burn down. In summary, I believe that our house saved us from the bush fire, but we had to escape from the house to survive the resulting house fire, which we could not fight because our equipment had been damaged.* (St Andrews)

> *At that stage we couldn't move to the south-west side of the tank (which would have given better shelter from the burning home) because there was a cedar cubby house on that side that was well alight ... The radiant heat now intensified to the point where it began melting both the torch and the water bottle by my right foot … There was fire and devastation all around us and it was clear to me that we could not stay where we were. It crossed my mind at that point that we might be in serious trouble!* (Callignee)

> *At about 5.45 pm, I was in the pool and the fire front passed over us. It lasted for 20–30 seconds. I recall looking out from beneath a blanket and seeing that the house was still standing but that grass, bushes, pot plants and trees were on fire. Two fires broke out on the second floor balcony of our house … The house itself was beginning to fill with smoke and I heard our smoke detectors going off. Once those fires had been dealt with, I noticed a fire coming from the direction of our wood fire box, which was behind a closed door … At about 6.00 pm, [name removed] and I then went back to the pool and watched the house burn down with [name removed] and [name removed] … At one stage while we were in the pool, I recall looking around and noticing that virtually everything that I could see was on fire. At about 6.20 pm, the heat from the fire became so intense that [name removed] and I decided to put our heads under water to cool off. While I was doing this, my camera touched the water and it stopped functioning.* (St Andrews)

Figure 10 Photo of burning elements (photo from VBRC reports, Teague et al., 2010).[26]

7.4 Health issues while sheltering

Many residents mentioned being affected by smoke with impacts on their health and decision making. Some were injured and presented with effects of exhaustion. They noticed difficulty breathing and, in some cases, acrid or toxic smoke. Some even described being strongly affected so that they almost 'pass out'.

> *As soon as I stood up, however, I nearly collapsed from lack of oxygen. I hadn't expected the smoke to impinge so markedly on my physiology*. (Callignee)

> *[There] was an eave and a lintel that were on fire. [name removed] and I – when you went outside, you couldn't breathe. So we would hold our breath, give three or four pumps onto that and then duck in and the other one would duck out and give another three or four pumps. Unfortunately, [name removed] got a bit excited and gave five and took a breath, at which point he buckled at the knees. I grabbed him by the collar and dragged him in and said, 'That's it.'* (St Andrews)

> *My wife and kids were having difficulty breathing. So there is a downstairs in our place because it is built on the slope, so I said, 'Let's go downstairs. [name removed] room hasn't been opened yet.' This is the bottom corner of the house. 'There might be a bit of air in there.' There wasn't a lot, but there was enough and we ended up in there on the floor, literally with our noses on the carpet.* (Steels Creek)

[26] http://vol4.royalcommission.vic.gov.au (accessed October 2015)

This one had an asthma attack mid-run down the road. So she was kind of half dragged, half carried. (Pheasant Creek)

Burning houses and surrounding objects release potentially toxic chemicals into the air resulting in increased health risks for people in the vicinity of the fire (Borgas et al., 2013). In most cases, residents sheltering within burning structures are exposed to air toxins released from the burning of natural and man-made materials. The emissions from both natural and mad-made materials are harmful. A range of combustible materials are present in urban areas (e.g. synthetic products, wood and manufactured products, polymeric materials or plastics, paper, electrical appliances, paints) (Reisen, 2011). Air pollutants resulting from the combustion of the structural material and furnishings that are of health concern include asphyxiants (e.g. carbon dioxide, carbon monoxide, hydrogen cyanide), other irritants (e.g. formaldehyde, acrolein, hydrogen chloride), and carcinogens (e.g. formaldehyde, polycyclic aromatic hydrocarbons). Exposure to carbon monoxide or hydrogen cyanide has a cumulative effect that can impair judgement and behaviour of residents if present at elevated concentration with acute exposure resulting in asphyxiation (Reisen, 2011). While irritant gases can damage the airways reducing the airways effectiveness. There are also many carcinogens present that can increase the likelihood of developing long term illnesses.

Reisen et al. (2014) studied the emissions of particles, aldehydes and speciated volatile organic compounds from the combustion of selected combustible materials commonly found in urbanised areas. The authors concluded that the highest concentrations resulted from the combustion of polymeric material (polyester insulation, polystyrene with cladding material, PUR foam and a wool/nylon carpet). To put it into perspective, wood-based products make up the majority of the mass in building structures so emissions from wood-based products may contribute more significantly to total emissions, and hence exposures, than emissions from polymeric materials. In addition to the emissions from burning wood component these wood based products can contain preservatives, glues, binders and coatings that can produce harmful gases when burnt.

Many people were affected by the heat and suffered from exhaustion, dehydration and injuries. Aisbett et al. (2007) studied the factors contributing to fatigue for firefighters. They discussed the fact that under sustained or increasing stress, fatigue may quickly lead to impaired work performance and judgement, unsafe behaviour and accidents (i.e. injury) (Aisbett et al., 2007). Appropriate clothing and footwear was also an issue resulting in burns for some residents. This issue was also raised in a police report (Hart, 2014) where the author noted that in a number of events where people died, a lack of proper clothing and footwear appears to have contributed to their deaths in the open space.

Access to the water was on the other side of the tank. … I managed to crawl on hands and knees around to the other side of the tank … I dunked the towels in the water and crawled back to [name removed]. I was nearly out of energy just from going that short distance so I said to [name removed] that we would have to take it in turns wetting the towels. (Callignee)

The wind had predominantly originated from the north west but had turned to the south west, bringing the flames to me at the garage. The flames burnt me on the arms, face and I had inhaled the heat and some smoke which burnt my airway. (St Andrews)

When I went out into that fire storm, it was like someone was placing a huge tube, like a sandblasting tube of embers and heat and just blowing it straight at me. That is how intense it was. He opened the door, I stepped out, took two or three steps, threw the buckets of water on the verandah [sic] enough to put it out and got back in. I don't know, it might have taken 15 or 20 seconds and I was all burnt around here. (Steels Creek)

Well, in the run from the house to the car, I had taken my gloves off by then, so in the space of, I don't know, about 10 steps perhaps, that was enough for me to get burns on the back of my hand on the side that was facing the embers and the radiant heat. (St Andrews)

The ground under our feet was also extremely hot, which I realised later was because we were actually standing on burning embers that were covered by ash. (Callignee)

I threw water at the door and noticed that the flames were coming from beneath the door. I went to open the door but [name removed] yelled at me and said that the fire would vent through the door if I opened it. I touched the door and it was extremely hot – it was clear that the whole room behind that door was on fire. I then looked up and saw that the flames were burning the second storey of the house and I realised that we could not save the house. (St Andrews)

The situation was extremely stressful for many residents – they experienced high levels of fear, anxiety and trauma.

We had suffered substantial smoke inhalation and were both extremely traumatised by the situation. (Callignee)

What was the experience like being in the bunker? Picture the worst possible scenario you can picture and that's virtually what it was. It was like a jet engine at the door. You couldn't see in there. The smoke was pretty intense in the container. You didn't have a clue what was going on around you outside. It was just one of the scariest experiences I have ever been in and I wouldn't like anyone to go through it again. (Clombinane)

7.5 Summary

Most people who sheltered were active, monitoring the fire inside and outside, protecting their shelter and occupants by extinguishing ignitions. However, there were households where one or more people sheltered inactively, often children and the elderly, while others defended or actively sheltered. Prior preparation was important in enabling people to monitor effectively while they sheltered e.g. having a ladder inside to check roof spaces. Monitoring was critical for assessing when it was safe to leave a place of shelter. There were a few cases where residents were not monitoring the fire and remained inside as houses caught fire and filled with smoke. If it was not for others who were actively defending and or monitoring these people sheltering would likely have died. Those who sheltered faced many challenges including the effect of the bushfires, noises and heat, caring for children, elderly and injured people. Some people recognised the magnitude of the fire event and the considerable efforts needed to survive under the weather conditions experienced that day. This highlights the danger and the risks associated with sheltering.

8 Failure of shelters

This chapter describes the experiences of shelter failure, focuses on house failure and some of the reasons that might increase the houses vulnerability. A range of statistical analyses were performed to examine the relationships between shelter location, the distance to forest, severity and survival. Finally, a multivariate linear regression analysis was performed between a single survival factor as the dependant variable and other variables contained in the dataset as independent variables.

8.1 Structural failure experiences

A large number of people experienced structural failure of their shelter. They faced major challenges and issues including 116 persons dying inside structures and 160 (out of 838) exiting a burning house and having to find a second, and sometimes a third, place of shelter (see Table 13). Although the numbers of examples are low in some categories, the data infers that the survival rate from burning shelters is poorest for residential building and best for other structures including commercial buildings. The higher survivability of occupants in commercial buildings is not a surprise given that they are subject to building controls that facilitate egress in the event of fire.

Table 13 Number of shelter failures while people were sheltering in them (forcing resident to exit or become trapped in the house).

Shelter type	Number of fatalities	Number of survivors	Total number of people
Bunker	2		2
Commercial building	4	11	15
Residential building	109	133	242
Other structure	2	16	18
Total	116	160	276

8.1.1 EXPERIENCES OF HOUSE FAILURE

Some residents described the conditions inside the house and their experiences of sheltering in a burning house. They described moving through the house and closing doors, discussing when to exit and noticing the issues associated with burning objects outside preventing them from exiting (See also Appendix 2 and Case Study 5, Figure 11).

> *At that stage we were still planning to stay in the house because I knew, having been outside, that we couldn't survive outside, so it was really a case of whether we could survive in the house long enough. I had basically written off the house, but I thought it would take some time to burn and that would give us time until things died down outside. But, as I said, I assumed the fire had gotten into the roof space and was burning quite strongly up there. The house began to fill with quite thick black smoke and flames were actually beginning to come down out of the ceiling and things at sort of ground level were beginning to catch fire, so we retreated slowly back through the house to that eastern end which was the furthest from the fire. That had a door out onto the verandah [sic], so in the end we were back huddled in that back corner of the house with the house rapidly filling with smoke. I mean, you couldn't see and you couldn't really breathe. It was at that point that I realised we had no option. It was either stay in the house and certainly die or go outside and maybe probably die, but at least we had a chance.* (St Andrews)

*The circumstances suggest that the [name removed] B house, like the [name removed] house, ignited rapidly, with the couple being incapacitated during the sheltering stage, before they had the opportunity to leave the house. (*Steels Creek, Police officer*)*

The eastern end of the house was alight so we closed off that end of the house and banked up the doors with wet towels … By this stage we were confined to two thirds of the house … In about another ten minutes, we could no longer defend the kitchen. The smoke got really bad and [name removed] said that we had to move to the next room … This was at about 6.00 pm, about an hour and a quarter after the first front or spot fire came through … After that, the fire started to die down. We began to see spots of light in the smoke and it was possible to go outside. (St Andrews)

Many people were able to recognise the threat presented by the burning house and were able to exit the house. A few residents gave vivid accounts of their experiences and depicted the considerable risks taken while sheltering and exiting a burning house.

What actually happened was that the fire storm impacted dramatically on the west side of the house. The windows blew in with tremendous force and the house essentially imploded. [name removed] and I were hiding behind a wall in the hallway at the time but I could see into one of the bedrooms. I saw the fire impinge so suddenly that it immediately filled the whole room. Very shortly thereafter the flames entered, the varnished surfaces of the built-in wardrobes and the paint on the walls caught alight. The atmosphere in the house became intensely acrid and it felt like my lungs were shutting down. One minute I was breathing and the next minute I physically couldn't inhale. It was at that point that I knew the house was lost because the impact of the fire was just too severe. The house sits on raised stumps and I knew that the timber joists that sit on the stumps would be burning and that the fire would quickly come up through the floor from underneath the house. I said to [name removed] that we had to get out of the house. (Callignee)

He found that the study at the western point of our house had been breached by fire and that it had entered the ceiling corner. He closed off this section by pulling the sliding door across and did the same with the nearby laundry door, finding flames now coming into this area too. Soon afterwards, we heard the laundry window explode … It was around this time I began to feel real fear. Although I never doubted we would make it through, my mind began to play tricks as I tried hard to keep focussed. At that point, I knew it was only a matter of time until we would have to leave the house. (Kinglake)

The objective was to stay inside the longer, the ignition was smouldering, it was not a threat immediately … There is a big window and it was spectacular outside, I have this image of the garden flaring up … Not a good place to be outside, the longer we stay inside the better. We are doing good work inside, my daughter was extinguishing ember inside, I was just keeping an eye on things. At one stage, I noticed there was a smoke layer starting to come down from the roof and it had a flame running along the bottom of it. I am not a structural fire fighter but I knew that was not a good thing. Because there a volume of staff burning at the bottom and the only reason that it is not getting enough oxygen. If for some reasons, we broke a window or some wind got in and stirred that up it would became a significant fire. I knew the inside of the house was not safe any longer, we need to be outside very quickly. (Strathewen)

Summary:

- Intention: Stay and defend
- Preparedness: Well prepared, written plan made with CFA, developed community fire guard with four neighbours, house built to standard
- Summary: House caught on fire, residents struggled to stay inside until last minute possible, exited to the shed not on fire
- House: Destroyed; Shed: Damaged
- People: 2 people (survived)

Account from resident:

> *At about 6.40 pm we retreated into the house as a wall of red rapidly grew before our eyes. By about 6.45 pm, all the trees around the house were burning and there was a deafening roar. The fire front had arrived at the edge of the clearing which surrounds our house and it skipped the clearing and hit the house almost instantly. The size of this clearing had been the subject of careful planning and we had made it larger than the size required by the Wildfire Management Overlay, with between 25 and 60 metres of bare ground between the house and the bush. Despite that, the clearing seemed to make no difference to the speed at which the fire hit our house, although it might have delayed it subtly and perhaps enough to help save our lives.*

I believe that the fire front struck the property at about 6.45 pm because we later discovered a partially melted clock in our shed which had stopped showing that time. When I saw the fire, I was initially mesmerised by the sight of it. Our house had floor-to-ceiling windows and I had a full view of the flames which at a guess would have been at least 30 metres high, moving horizontally, smacking into the side of the house and wrapping around it. It was as though the house had been picked up and thrown into a sea of fire.

I noticed at about that time that our water pump had failed and it was then that I realised we were in 'Scenario Z' – or in other words, that we should not have been there. We were experiencing the worst possible bushfire conditions and all of sudden we only had mops and buckets to fight the fire. In accordance with our fire plan, we retreated into the laundry on the north-eastern corner of the house, being the opposite side from which the fire front had approached. Within two minutes, some of the windows around the house came crashing in, allowing fire to enter the house.

We stayed in the laundry for approximately 15 minutes, lying on the floor and trying to get oxygen as smoke started to enter the laundry. During this time, we deliberately spoke to one another continuously because it was difficult to breathe and we were worried about losing consciousness. I recall [other resident] saying that he could not breathe and at one stage he put his head in a cupboard. I told him firmly to get out of the cupboard but otherwise, most of our talk was commentary on what was happening. I looked at my watch every minute or two and tested the temperature of the air regularly by raising my hand. I remember saying things like, 'Door's hot now, just hang in there another few minutes. Our teamwork during these critical few minutes was vital in saving our lives.

Towards the end of our stay in the laundry, I recall noticing that the floor tiles were getting hot and it was apparent that the fire had spread to the sub-floor. At about 7.05 pm, I was beginning to seriously struggle for breath and the remaining inch of cleaner air low down next to the floor tiles had filled with a whitish layer of thick acrid smoke. I knew we were getting close to losing consciousness. I told [other resident] that we should evacuate from the house and I took his hand and led him out of the house and down the back steps which were already on fire. We then ran across to the nearby shed and went inside. The shed had been hit by the fire front but it had not ignited. There was a small fire burning inside which I quickly put out. We slammed the roller doors closed and got in the car where we lay down. By now, the fire front had passed through but the fire had taken hold of the house and the air was still extremely hot.

Figure 11 Case Study 5: Example of shelter failure and evacuation from a burning house (built to regulation). This image shows the extent of the devastation surrounding the shelter locations.

These accounts raise a number of key questions around how bushfire related building controls can:

- Improve the predictability of house failure
- Reduce the rate of building tenability loss
- Facilitate egress

These points have been previously highlighted as potential deficiency is some bushfire related building standards (Leonard, 2009).

8.1.2 WIND DAMAGE TO SHELTER BEFORE FIRE FRONT ARRIVAL

High winds during a bushfire event have the potential to cause superficial or major damage to buildings. This can occur before during or after the passage of the fire. In each case even superficial wind damage can render a building more vulnerable to the other effects of the bushfire. The key damage processes are damage to the building façades, windows breakage and lift roof materials. Winds can also provide an air pressure difference that can force flames through small gaps in the building envelope, increase the rate and extent to which building elements lose moisture and increase the intensity and distribution of embers and

combustible debris that reaches or enters the building (Blanchi et al., 2011). In addition, winds make survival outside of the protection of a building difficult. An able-bodied person may have some difficulty walking in winds greater than 54 km/h (15 m/s) (Blanchi et al., 2011).

Some example of reports of major wind damage are provided below.

> *Had the roof not lifted, the house would have fared much better during the fire. Once the roof sheets became detached, the sprinkler system would have been rendered ineffective and the contents of the house would have been open to direct fire attack, probably in multiple areas in a short period of time. The occupants would have struggled to extinguish multiple fires within the home at the time of the firefront passing through the property, and they would have been exposed to extreme temperature, wind and smoke.* (Steels Creek, Police officer)

> *I mean these are jarrah, they're quite heavy. It went flying behind me and then virtually the same gust of wind blew apart our glass doors into the lounge room. It blew the deadlock off the door. The lock is still locked and that's when I panicked ... Embers and leaves were just pouring into the lounge room. So I raced back inside and propped the dining room table against the flying embers.* (Humevale)

Leonard et al. (2009) reported that 13% of houses surveyed after the fire (135 houses) were affected by wind (such as missing roof tiles, lifted roof sheeting or missing sheeting from eaves). Wind was identified as a mechanism that compromises the structure of a building and makes it more vulnerable to fire. In at least two confirmed cases, wind alone was identified as seriously affecting structures with no associated fire damage. Leonard et al. (2009) pointed out that evidence of wind-related effects is difficult to identify from burnt house wreckage and that the proportion of houses affected by wind is likely to be substantially greater than is represented the 13% figure identified in the post bushfire survey. Hart (2014) mentioned that there were at least 15 events where people died and the accompanying structures showed evidence of wind damage. The author also mentioned that wind damage was a significant contributing factor in 12 of those events.

This raised the question of whether our current building design standards adequately address wind related damage. Leonard (2009) identifies the issue of AS3959 not addressing the issue of superficial wind damage of regulated structures.

8.1.3 TENABILITY OF SHELTER

The duration that residents sheltered varied substantially. Some mentioned that they sheltered from a few minutes to up to an hour during the passage of the fire front (Table 14). In other cases, consequential fire following passage of the fire front occurred over many hours and extended the time that sheltering was needed. This could be attributed to the severity of the weather conditions on the day, as well as building and landscaping design (Leonard et al., 2009a; Teague et al., 2010).

Table 14 Example of timing (duration of shelter time according to people).

Cases	Time (according to resident) in minutes
We stayed inside for probably 10 or 15 minutes … When everything stopped burning outside we went outside to put fires out. (Buxton)	10–15
The fire fronts took about thirty minutes to pass through our property. Once it did, we remained in the fire bunker for about five hours. (Clonbinane)	30
The next 30 minutes inside the house was the worst time. We saw that we were now surrounded by this incredible overhead red glow in all directions and we realized that we were surrounded by fire. (Buxton)	>30
… By this time we were probably 40 to 45 minutes into the fire being around us, yes. (St Andrews)	40–45
…. after about eight minutes or so, that the house was already on fire, … we obviously had to evacuate the house. By this stage the fire front itself had passed but our house and several parts of our property were on fire. (St Andrews)	8
… how long was the house surrounded by fire? Well, this was a bit of a surprise to us. Although we hadn't lived through a fire before, we had read literature that suggested that fire takes about 20 minutes to go through. This fire took over an hour and we were sort of actively fighting it for that entire period. (Strathewen)	60
So we'd do patrols and Matthew kept timing us. That's how I was pretty – I'm pretty adamant on the time it took to pass us, which was about 45 minutes. So that's what we did. (Steels Creek)	45
We couldn't see the fire once we were in the classroom but we could hear it approaching. We were in the classroom for about 15 minutes … I saw that the fire had passed the oval. (Strathewen)	15
The fire reached the house at around 8.00 pm. A rush of flame came up to the house and surrounded it for 10 to 15 minutes. We sheltered inside the house for perhaps an hour. (Reedy Creek)	10–15 (shelter longer)
At about 5.45 pm, I was in the pool and the fire front passed over us. It lasted for 20–30 seconds … At one stage while we were in the pool, I recall looking around and noticing that virtually everything that I could see was on fire. At about 6.20 pm, the heat from the fire [from surrounding burning] became so intense that [resident] and I decided to put our heads under water to cool off. (St Andrews)	0.5 (affected more than 30 min by surrounding objects burning)
My recollection of time is all distorted. I think the fire front hit between 4.30 pm and 4.45 pm … it felt like I was in there forever. I am guessing it was only between five and ten minutes. (St Andrews)	15
The main fire front seemed to last about 20 minutes. (Callignee)	20

After the main passage of fire some people needed to find alternative places to shelter that survived the fire front, or needed to stay longer in their current shelter location.

> *I then went back inside the house but [name removed] and [name removed] had already gone outside, they were sheltering behind the car. By this stage the fire front itself had passed, but our house and several parts of our property were on fire? Yes. … Is that the best of your recollection? Yes. So it was after the fire front itself had passed that the activity concerning the car that you have described occurred? Oh yes. If the fire front hadn't passed we would have been dead leaving the house. The house saved our lives.* (St Andrews)

> *Once you got into the container, for how long were you and your family in there before you came out? My wife reckons the fire pretty much hit the door within 30 seconds of me getting there. She was holding that door closed because it doesn't have an internal lock on it. We were in there for a good half an hour while that was going on. After that we looked out every now and again but it was too hot to come out. We were in there until about midnight.* (Clombinane)

Some residents reported issues with the tenability of the building. For example, combustible elements around the house like cars created additional exposure on the house. In addition, multiple ignitions needed to be addressed in a short amount of time. If the ignitions are not addressed quickly then they can develop to a point that cannot be suppressed by the occupant. The building design would govern the number of multiple ignitions possible.

> *One of the mistakes I have made is to bring all the cars around the house to protect them, my daughter horse float. In the scheme of things, the house was going to burn down but this did not help it. These [cars] all caught fire and produced a significant heat load on this end of the house and caught that on fire much quicker. Possibly reduce the amount of time you could survive in the house… The wind was certainly the problem, I had this neat idea that embers attack is lovely snow flake if you are looking after your gutter you are ok. But the reality is that the embers were blowing up the roof and getting into the ridge line. That's were the first fire occurred in the ridge cap on the ridge beam above the lounge room six meters above the floor … I was going to put some insulation but I never did.* (Strathewen)

Residential houses were the most common places to shelter. One of the main challenges with sheltering within house is their complexity. They have many occupiable and non-occupiable compartments. Unless specifically designed these compartments are made-of or contain combustible elements. An occupant is faced with the task of monitoring all of these compartments and having the resources to address any fire starting within them (some house compartments for example in roof or underfloor are more difficult or impossible to monitor).

A key challenge is the ability to recognise the houses ignition and the circumstances where these ignitions develop beyond the capability of the occupants to suppress them. In these cases, the occupant needs to recognise the inevitability of leaving a house that has developed past the point of being able to suppress it. The rate in which the house losses tenability from this point is a function of house design, whether door in the house are open or closed and the nature of the developed fire. The fire could develop at a rate that is faster than what is anticipated by the occupants. This may occur through a range of different process like:

- The house rapidly filling with smoke.
- The floor or ceiling collapsing.
- Rapid flame spread through the house as one or more rooms or building cavities 'flashover'. Flashover occurs when smoke that is layering in the room reaches a concentration level which it is combustible, hence the smoke burns as a large plume and engulfs the room.
- Items in or near to developing fire exploding.
- Occupants need to locate themselves at the most viable exit locations in anticipation of this occurring. The most viable exit will need to consider the location of the developing house fire(s), the presents of combustible elements attached to or near the house exit and the location(s) outside to could provide them the most likelihood of survival.

8.2 Spatial analysis

A range of statistical analyses were performed using the categorical data extracted from the interviews, witness statements, other sources and the spatial analysis. The relationships between shelter location, the distance to forest and fire severity were examined in all cases.

8.2.1 FIRE SEVERITY AND DISTANCE TO FOREST

Relationships between shelter damage, fire severity (Figure 12) and distance to forest (Figure 13) were examined.

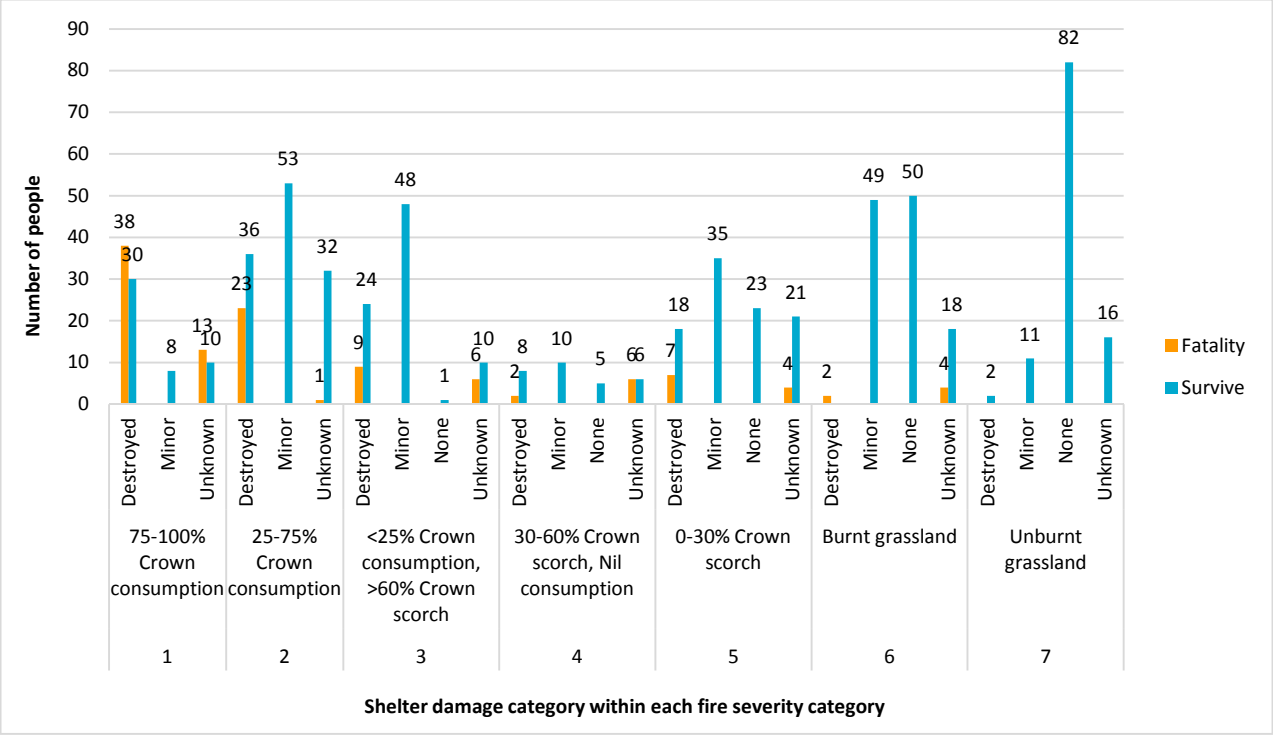


Figure 12 Survival by shelter damage and fire severity. Note that fire severity is only available for the 2009 Kilmore East bushfire.

The areas most severely affected by the fire (75% crown consumption) represented the most fatalities in destroyed houses (*n*=38). However, in this category, some people managed to survive the fire even when the house was destroyed (*n*=30). thus it is possible to get good predictions of house loss provided the exposure is known. It was not possible for this study to estimate the fire impact at the level of each shelter location. However, in their study of fire behaviour measures and community loss Harris et al. (2012) and Kilinc et al. (2013) found that an estimate of the energy released from the fire front using Byram's intensity (Byram, 1959) was the best predictor of house loss. Harris et al. (2012) also indicated that life loss was closely related to fire behaviour.

If we look at distance to forest with respect to the cumulative percent of people, over 90% of locations are within 100 m of forest (see Figure 13). The data identify that 59% of fatalities were in sheltering locations within 5 m of forest and 90% within 35 m. Conversely, 50% of survivals were in sheltering locations within 15 m of forest and 90% at 90 m. From this we can state that a greater proportion of fatalities occurred closer to forest.

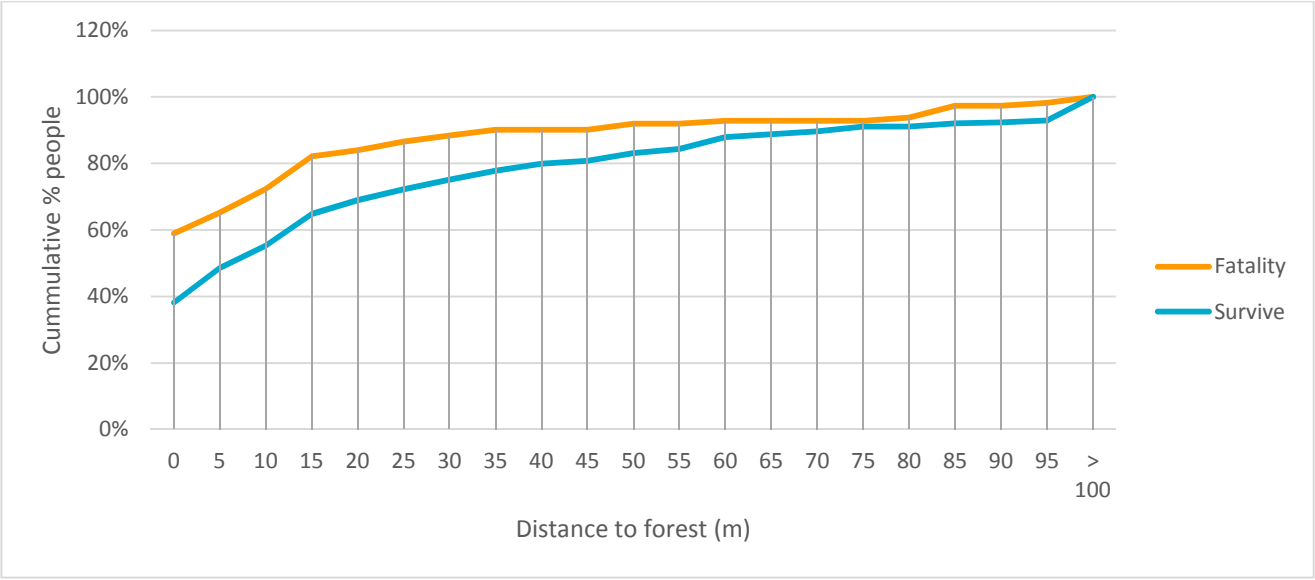


Figure 13 Cumulative percent of people with respect to their location to forest, in metres, and survival.

8.3 Statistical analysis of shelter location data

The significance of individual variables on the probability of survival was examined. A general linear model was used that tested survival at sheltering locations. The most significant variables ($Pr(>|z|) < 0.1$) were the number of active people, the number of people sheltering, the distance to forest and the fire severity (Kilmore East fire only) (see Appendix 3).

We aimed to determine if there was an identifiable individual variable or combination of variables that had the largest impact on the chance of an individual's survival. The predictive power of the collected data in determining survival was most significant for the number of active people sheltering and the number of people sheltering. Other data that had an impact were the lower number of shelter locations, fire severity (only available for the Kilmore East fire), whether or not the shelter was outside of forest, the distance to the forest and whether they were a resident. A sample bias may exist in the data where the lower number of shelter locations had a positive impact (See Table 16 in Appendix 3).

Of the more significant predictors on the success of survival the pseudo r^2 was determined (Table 17 in Appendix 3). The pseudo r^2 can be interpreted as an estimate of the improvement in the model relative to an 'empty' model with no predictors. The different methods (McFadden's, maximum likelihood estimation, and Cragg and Uhler's pseudo r^2) use various corrections, but are conceptually similar.

By comparison, the number of people who were active while sheltering, which had the best score given the metrics to assess general linear models, also scored best in pseudo r^2 (0.08–0.13). It is not suitable to use this individual variable as a predictor for determining the probability survival given these r^2.

The significance of a combination of variables on the probability of surviving sheltering was also assessed. This data was restricted to complete dataset records, which included only locations that were used as a shelter. To explain this further, 102 residences belonging to people (n=214) who were sheltering elsewhere were not used as a shelter location. This gave us 380 sheltering locations to use for the combined variable analysis.

The most reliable model in estimating survival included the number of active people sheltering, the number of people sheltering, location outside of a forest and a shelter location with little to no damage. These variables combined have an area under receiver operating (AUROC) curve of 92%. This means that high discrimination (percentage of successful classification) exists when randomly drawn pairs are tested with the model. The combination of these variables shows an improvement in the pseudo r^2 when compared to using the individual variables (Table 15).

Table 15 The pseudo r^2 of the combined variables most significant in predicting survival in a shelter.

Log likelihood	Log likelihood for null model	Minus two times the difference in the log-likelihoods	McFadden's pseudo r^2	Maximum-Likelihood's pseudo r^2	Cragg and Uhler's pseudo r^2
-116.06	-220.03	207.92	0.47	0.42	0.61

This analysis shows that of the data collected, independently, the number of people actively sheltering had the strongest influence on the probability of surviving in a sheltering location. However, a higher determination of survival is described by a combination of the following:

- a higher number of people actively sheltering
- a slightly higher number of people sheltering
- not being in forest
- little or no damage to the shelter location.

8.4 Summary

People's account on shelter failure highlighted the considerable risks taken by residents when exiting a burning building and the difficulties experienced to find another place of shelter. Key challenges were the ability to recognise the houses ignition and being able to extinguish any fire starting within them.

For those actively sheltering in the house, occupant fatalities occurred either because the occupants were overwhelmed by the rate at which the house lost tenability or they failed to recognise the developing house fire. Building regulation could play a prominent role in specifying provisions that reduce the rate of tenability loss and reduce the prevalence of cavities where fires can develop without the occupants being aware. Currently AS3959 (Standards Australia, 2009) does not identify either of these factors in its considerations while the NASH standard[27] does.

The statistical analysis emphasised the relevance of active sheltering and the benefits of group dynamics in improving survival prospects. With the interesting fact that these stand out above other considered factors in the study including those that are strong obvious factors like forest proximity and shelter status.

[27] http://www.nash.asn.au/nash/home.html (accessed October 2015)

9 Policy implications and conclusion

This project aimed to examine the circumstances and challenges experienced by residents when sheltering during the 2009 Black Saturday bushfires. The research utilised multiple data sources including VBRC witness statements and interviews with affected residents. In addition, data on several variables were collected to assist in developing the context under which people sheltered (e.g. sheltered location, proximity to forest, fire severity).

The analysis of witness statements and interviews provided a number of insights into people's behaviour and experiences when sheltering during bushfires. The data suggested that most people had not anticipated they might need to take shelter during a bushfire, or given much consideration to what they would do if they needed to shelter. Those who intended to stay and defend were more likely to have considered the need for shelter, often envisaging they would shelter inside during the main passage of the fire front and then exit the house to continue defending when it was safe to do so. This approach was consistent with the advice provided by fire agencies. People who intended to leave were less likely to have considered the need for shelter. Only a very small number of residents identified the intention to shelter as their primary strategy.

Levels of planning and preparation for sheltering were varied. Most residents' planning and preparation focused on measures to improve their prospects to either stay and defend against bushfire, or leave safely. Only a small number of residents planned specifically for what they would do if they needed to take shelter, and even fewer had identified places they could go if they were unable to shelter inside the house. Nevertheless, a very small number of residents took steps to design, construct and retrofit houses and other buildings to improve their safety during a bushfire. However, most of those who ended up sheltering during the fires made relatively few preparations specifically for sheltering. Importantly, the sudden arrival of the fire meant that many residents were unable to complete all of their planned preparations, which compromised their ability to safely shelter.

For those who intended to defend, the main triggers for taking shelter were the arrival of the fire front, the intensity of the radiant heat, flames, embers, wind and noise. Some sought shelter because their attempts to defend the house were unsuccessful, or because they were injured or overcome by heat and smoke. The sudden arrival of the fire prevented many of those who intended to leave from leaving, while others attempted to leave but were forced to return to their property to take shelter, or take shelter in their car.

People sought shelter in a range of locations and shelter types. People most commonly sheltered inside houses (60%), while around 12% sheltered inside commercial buildings such as hotels, pubs, wineries and ski huts. A large number of residents and fire personnel sheltered at the CFA sheds. Occasionally people sheltered in sheds, bunkers or open spaces such as sports ovals or paddocks; alternatively, they found protection in pools, dams or rivers. Some residents left their own properties and sheltered at a neighbour's house or at other buildings and locations such schools, pubs, sporting clubs and ovals.

For those who sheltered within houses, the location and movement of people varied considerably. Some people sheltered in specific locations such as a bathroom or pantry with poor visibility to outside conditions (37% of people with a known location), or in other parts of the house such as a bedroom, hallway, kitchen or laundry. Findings also support past research (Blanchi et al., 2012; Krusel et al., 1999; McArthur et al., 1967) that suggests some people believe bathrooms to be the safest room in which to shelter. The perceived safety of the bathroom appears to stem from the ready availability of water and the contained nature of the room. It is noteworthy that children and pets were often confined to bathrooms, with and without the presence of adults.

Others moved around the house in order to monitor the fire outside and possible ignitions outside and inside the house. Due to the severity of the 2009 bushfires, some shelters failed and people had to seek alternative options. Some residents used as many as three separate shelter locations. A summary of these data showed that 84% of people survived in their first location of sheltering. Subsequently, of the 12% of people who moved to a second location, 87% survived. Finally, 2% of people moved to a third location where all of them survived.

In cases where occupants exited a burning house, the most common places used as secondary shelters were open space, sheds, bunkers, dams, and other houses. Open space was the most prevalent place of shelter for the second location of shelter (*n*=64).

This research has drawn a distinction between active and inactive sheltering. Active sheltering involves regular monitoring of the fire and conditions inside and outside of the house, or actions to protect occupants such as extinguishing fires; preventing the entry of smoke; and caring for children, the elderly and those who may have been injured. Inactive sheltering involves a lack of regular monitoring and actions to protect occupants. Most residents actively monitored the fire outside, as well as potential ignitions on and inside of the house or building. It was common for some members of the household to shelter inactively, particularly children and the elderly; however, they were almost always protected by other members of the household who were actively defending and/or actively sheltering.

Statistical analysis of the data showed that the number of people actively sheltering had the strongest influence on the probability of surviving in a sheltering location. This emphasises the relevance of active sheltering and the benefits of group dynamics in improving survival prospects. These factors stood out above all others, including obvious factors like forest proximity and shelter status, in determining probability of survival.

Analysis of the witness statements and interviews revealed many of the challenges faced by people who shelter during bushfires. The presence of infants and very small children meant that some adults were less able to assist in defence of the house, or regularly monitor what was happening inside and outside. This was particularly because children were often kept in bathrooms and other 'protected' spaces within the house where access and visibility were limited. Some residents were also challenged by the presence of people who were injured in the fires and required ongoing care and attention. Residents also described the challenges associated with exiting a burning house and finding a safe place to shelter. In addition, combustible elements such as vegetation, cars, garden furniture and woodpiles, or elements that lost structural integrity such as decks and stairs, made egress difficult or impossible for residents. These difficulties support the findings of Blanchi et al. (2012), where 40% of fatalities (*n*=31) were found to have occurred in close proximity to the home (<20m). These findings emphasise the need to consider egress as part of bushfire planning and building policy frameworks.

An important finding from the research relates to informal, locally organised 'safe houses' and 'community refuges'. The research identified a number of self-designated 'safe houses' that residents had planned to shelter in during a bushfire. In a number of cases, residents' expectations of sheltering safely at these houses were ill founded. Other residents had identified informal 'community refuges' where they believed they could shelter safely, including open areas such as sports grounds and local hotels and pubs. The need for a community refuges was strikingly apparent in Marysville. Despite some confusion over the 'designated refuge point', residents commonly believed they would be able to shelter safely at Gallipoli Park oval, the Marysville Golf Club and the Cumberland Hotel. People survived at both the oval and golf club. However, there were multiple fatalities in the Cumberland Hotel and one person died attempting to reach these locations during the fire event. These findings suggest the need for clearer advice about where to shelter during bushfires and how to decide when it is not safe to attempt to reach these locations, particularly if residents do not plan to shelter on their own properties. This has been partly addressed through the introduction of Community Fire Refuges and Neighbourhood Safer Places.[28] Residents should also be encouraged to discuss their plans for sheltering with others, particularly when they intend to shelter at a neighbour, relatives or friend's property, or at some other 'public' place such as a CFA shed, hotel or sporting club.

The research identified a number of beliefs about sheltering that may influence people's behaviour during bushfires. While most people believed that houses are relatively safe places to shelter, others questioned whether houses could survive bushfires in extreme conditions and therefore whether it was safe to shelter in them. Fears that houses will explode due to pressure or heat and that fire will suck oxygen out of houses

[28] For example http://www.saferplaces.cfa.vic.gov.au/cfa/search/default.htm (accessed October 2015)

discouraged some people from sheltering inside. One interviewee even opened windows in his house to prevent the build-up of heat, which he believed would cause the house to explode – this action inadvertently increased the risk of embers reaching the interior of the house. Greater uptake of information about how houses and other structures are impacted by bushfire is needed to help residents make more informed decisions about sheltering. Some of the occupants' accounts identified rapid loss of house tenability at a rate that could challenge a well-informed and vigilant occupant. This suggests that improved building prescriptions that take egress into consideration could reduce future losses of life during bushfire.

Analysis of the interview data suggests that many people considered building a 'bunker' or other structure in which they could shelter in future bushfires. Support for personal bushfire bunkers was high, with some people believing they should be compulsory in areas of high bushfire risk. Some people believed they could construct 'fireproof' structures that would guarantee their safety in a bushfire. There was also support for community bunkers or refuges. However, some people were concerned that bunkers and other such structures would not provide adequate protection in the most 'extreme' bushfires. They feared that bunkers might fill with smoke, oxygen would be sucked out, and that structures might collapse onto occupants. It was also suggested that the presence of a bunker could encourage people to wait until the last moment before deciding whether to stay and defend, leave, or take shelter. These accounts emphasise the important role of awareness and risk perceptions in residents' sheltering decisions and behaviours. Hence it may be beneficial for building regulations to provide prescriptions that address building performance and the perception of building performance.

A smaller number of residents considered designing and rebuilding their houses to enable safe sheltering in bushfires. Anticipated features of these houses included the use of fire resistant materials, fewer points on the house for embers to lodge, sprinkler systems, and larger cleared areas around the house. Some residents also considered building their houses into hillsides and covering them with earth. Future research should investigate the extent to which residents affected by the Black Saturday bushfires have designed and constructed houses to enable safe sheltering and their beliefs on how effective those measures would be, and the number and types of bunkers or other structures constructed to enable sheltering.

People who were well prepared for bushfire generally had better survival prospects than others. However, there were many examples where well prepared occupants were overwhelmed by the enormity of the defence task and the rate at which houses lost tenability. Policies that encourage occupants to leave are likely to reduce the number of people faced with these circumstances; however, it is unlikely that they will result in complete evacuation due to the broad range of factors that influence people's decisions to stay or go. Given that over 70% of deaths and 60% of houses lost in bushfires occurred on days exceeding FFDI 100, the question now remains whether building and planning regulation should more specifically target the circumstances leading to loss in these events. This can be specifically addressed by:

- egress provisions in house and urban design
- fragility of houses in extreme fire weather events with particular attention to wind effects
- robustness principles on building design codes
- role of heavy fuels in landscaping design to improve egress provisions
- building regulations and design to provide warranted confidence in the reliability of the building as a temporary shelter.

This research highlights that safe sheltering requires considerable planning and preparation by residents. Regardless of whether they intend to stay and defend or leave, residents should identify multiple places where they can go in the event that they need to take shelter. It is important that residents shelter actively by continually monitoring conditions inside and outside the house, and by taking action to protect shelter occupants. Critically, sheltering should always be planned for as a contingency in the event that property defence or evacuation is not possible. There is a risk that greater provision of sheltering information and shelters may give people a false sense of security, encouraging them to wait until the last moment before taking action. This could increase the risk that people are caught sheltering with minimal or no preparation,

or that they undertake late and dangerous evacuations. Nevertheless, there is a need for public information to encourage planning and preparation for sheltering, and safe sheltering behaviours. The findings of this research indicate that safe sheltering requires appropriately designed and located shelters that are occupied by residents who are prepared and shelter actively. Information should emphasise that sheltering is not an alternative to leaving early or defending but may be necessary as part of defence or when early evacuation is not possible.

10 References

Aisbett, B., Phillips, M., Sargeant, M., Gilbert, J., & Nichols, D. (2007). Fighting with fire - How bushfire suppression can impacton fire fighters health. *Australian Family Physician*, *36*(12), 994–997.

Barrow, G. J. (1945). survey of houses affected in the Beaumaris fire, January 14, 1944. *Journal of the Council for Scientific and Industrial Research*, *18*(1).

Blanchi, R., & Leonard, J. (2008). Property safety: judging structural safety. In Handmer & Haynes (Eds.), *Community Bushfire Safety* (pp. 77–85).

Blanchi, R., Leonard, J., Haynes, K., Opie, K., James, M., Kilinc, M., Dimer de Oliveira, F., & Van den Hornet, R. (2012). *Life and house loss database description and analysis - Final report*. Melbourne: CSIRO, Bushfire CRC report to the Attorney-General's Department. CSIRO EP-129645.

Blanchi, R., Leonard, J., Haynes, K., Opie, K., James, M., & Oliveira, F. (2014). Environmental circumstances surrounding bushfire fatalities in Australia 1901-2011. *Environmental Science and Policy*, *37*, 192–203.

Blanchi, R., Leonard, J., Holland, M., & Kearsley, D. (2011). *Community Vulnerability Discussion Paper: Wind, Interface Fuels and Egress* . CSIRO Ecosystem Sciences, CSIRO Climate Adaptation Flagship, Australia, report to the Country Fire Authority.

Blanchi, R., Lucas, C., Leonard, J., & Finkele, K. (2010). Meteorological conditions and wildfire-related houseloss in Australia. *International Journal of Wildland Fire*, *19*(7), 914–926.

Borgas, M. S., & Reisen, F. (2013). *Bushfires extending into the rural-urban interface. Assessment of fire and emergency service workers' exposures to the complex mixture of toxic air pollutants at the rural-urban interface and the likely health risks*. Melbourne.

Bushnell, S., Balcombe, L., & Cottrell, A. (2007). Community and fire service perceptions of bushfire issues in Tamborine Mountain: what's the difference. *The Australian Journal of Emergency Management*, *22*(3), 3–9.

Byram, G. M. (1959). *Combustion of forest fuels*. in Davis K.P. Byrma G.M. Krumm W.R. Forest fire - Control and use. McGraw-Hill Book Co., New York.

Cohen, J. D. (2000). Preventing disaster. *Journal of Forestry.*, *98*(3), 15.

Cova, T. J., Drews, F. A., Siebeneck, L. K., & Musters, A. (2009). Protective Actions in Wildfires: Evacuate or Shelter-in-Place? *Natural Hazards Review*, *10*(4), 151–162.

Cruz, M. G., Sullivan, A. L., Gould, J. S., Sims, N. C., Bannister, A. J., Hollis, J. J., & Hurley, J. J. (2012). Anatomy of a catastrophic wildfire: The Black Saturday Kilmore East fire in Victoria, Australia. *Forest Ecology and Management*, *284*, 269–285.

Gill, a M., & Stephens, S. L. (2009). Scientific and social challenges for the management of fire-prone wildland–urban interfaces. *Environmental Research Letters*, *4*(3), 034014.

Handmer, J., O'Neill, S. J., & Killalea, D. (2010). *Review of fatalities in the 7 February 2009 bushfires.*

Handmer, J., & Tibbets, A. (2005). Is staying at home the safest option during bushfires? Historical evidence for an Australian approach. *Environ. Hazards*, *6*(2), 81.

Handmer, J., & Tibbits, A. (2005). Is staying at home the safest option during bushfires? Historical evidence for an Australian approach. *Environmental Hazards*, *6*(2), 81–91.

Harris, S., Anderson, W., Kilinc, M., & Fogarty, L. (2012). The relationship between fire behaviour measures and community loss: an exploratory analysis for developing a bushfire severity scale. *Natural Hazards*, *63*(2), 391–415.

Hart, D. (2014). *Lessons learnt from the black Saturday bushfires information for fire agency managers of community safety*. Victoria Police report to the Bushfire Cooperative Research Centre, East Melbourne, Victoria.

Haynes, K., Coates, L., Leigh, R., Handmer, J., Whittaker, J., Gissing, A., Mcaneney, J., & Opper, S. (2009). 'Shelter-in-place' vs. evacuation in flash floods. *Environmental Hazards*, *8*(4).

Haynes, K., Handmer, J., McAneney, J., Tibbits, A., & Coates, L. (2010). Australian bushfire fatalities 1900-2008: exploring trends in relation to the 'Prepare, stay and defend or leave early' policy. *Environmental Science & Policy*, *13*(3), 185–194.

Inspector General Emergency Mamagement. (2015). *Review of cyclone and storm tide sheltering arrangements*. Queensland Governmen, Brisbane.

Kelle, U. (2007). The development of categories: Different approaches in grounded theory. Chapter 9. In Bryant & Sage (Eds.), *The Sage Handbook of Grounded Theory*.

Kilinc, M., Anderson, W., Anderson, D., & Price, B. (2013). *On the need for a bushfire scale that represents the bushfire hazard*. Melbourne: Monash University bushfire CRC report to DSE.

Kissane, K. (2010). *Worst of Days: Inside the black Saturday firestorm*. Hachette UK.

Krusel, N., & Petris, S. N. (1999). *A Study Of Civilian Deaths In the 1983 ash wednesday bushfire victoria*. *CFA Occasional Paper No 1*. Mt Waverley: Contry Fire Authority.

Lazarus, G., & Elley, J. (1984). *A study of the effect of household occupancy during the Ash Wednesday bushfire in Upper Beaconsfield, Victoria, February 1983*. *NCRFR technical paper ; no. 3.* Melbourne Caulfield East, Vic.: National Centre for Rural Fire Research; Chisholm Institute of Technology.

Leonard, J. (2009). *Report to the 2009 Victorian Bushfires Royal Commission. Building performance in bushfires*.

Leonard, J., & Blanchi, R. (2005). *Investigation of bushfire attack mechanisms involved in house loss in the ACT Bushfire 2003*. CSIRO Manufacturing & Infrastructure Technology.

Leonard, J., Blanchi, R., Leicester, R. H., Lipkin, F., & Black, J. (2009). Profiling urban interface vulnerability. *Fire and Material 2009 11th Conference*. 26-28 January 2009, San Francisco, USA.

Leonard, J., Blanchi, R., Leicester, R., Lipkin, F., Newnham, G., Siggins, A., Opie, K., Culvenor, B., Cechet, B., Corby, N., Thomas, C., Habili, N., Jakab, M., Coghlan, R., Lorenzin, G., Campbell, D., & Barwick, M. (2009). *Building and Land use planning research after the 7th February 2009 Victorian bushfires. Preliminary findings*. Melbourne: Interim report USP2008/018 - CAF122-2-12 .

Leonard, J., & Bowditch, P. (2003). Findings of studies of houses damaged by bushfire in Australia. *3rd International Wildland Fire Conference*. Sydney 3-6 October 2003.

Leonard, J. E. (2003). People and property – a researcher's perspective. In Cary, Lindenmayer, & Dovers (Eds.), *In Australian Burning: Fire Ecology, Policy and Management Issues* (G. Cary, D). Melbourne, Vic: CSIRO Publishing.

Luke McArthur, A.G., R. H. (1978). *Bushfires in Australia. Reprinted with corrections 1986*. Canberra Publishing and Printing Co.

Lymburner, L., Tan, P., Mueller, N., Thackway, R., Lewis, a, Thankappan, M., Randall, L., Islam, a, & Senarath, U. (2011). *The National Dynamic Land Cover Dataset*.

Manzello, S. L., & Foote, E. I. D. (2012). Characterizing Firebrand Exposure from Wildland-Urban Interface (WUI) Fires: Results from the 2007 Angora Fire. *Fire Technology*, 1–20.

Mason, M., Haynes, K., & Walker, G. (2013). Cyclone Tracy and the road to improved wind resistant design. In Palutikof, Karoly, & Boulter (Eds.), *Natural disasters and adaptation to climate change*. Cambridge University Press.

McArthur, A. G. (1967). *Fire behaviour in eucalypt forests*. *Leaflet No. 107.* Comm. of Australia For. & Timber Bur.

McArthur, A. G., & Cheney, N. P. (1967). *Report on the southern Tasmanian bushfires of 7 February 1967*. Hobart: Forestry Commission Tasmania.

McCaffrey, S. M., & Rhodes, A. (2009). Public response to wildfire: Is the Australian 'stay and defend or leave early' approach an option for wildfire management in the United States? *Journal of Forestry*, *107*(1), 9–15.

McGee, T. K., & Russell, S. (2003). 'It's just a natural way of life…' an investigation of wildfire preparedness in rural Australia. *Environmental Hazards*, *5*(1), 1–12.

McLennan, J. (2010). *Use of informal places of shelter and last resort on 7 February 2009*. Melbourne.

McLennan, J., Elliott, G., & Omodei, M. (2012). Householder decision-making under imminent wildfire threat: stay and defend or leave? *International Journal of Wildland Fire*, *21*(7), 915–925.

McLennan, J., Elliott, G., Omodei, M., & Whittaker, J. (2013). Householders' safety-related decisions, plans, actions and outcomes during the 7 February 2009 Victorian (Australia) wildfires. *Fire Safety Journal*, *61*, 175–184.

Miller, S., Carter, W., & Stephens, R. (1984). *Report of the Bushfire review Committee on Bushfire Disaster Preparedness and Response in Victoria, Australia, Following the Ash Wednesday Fires, February, 16, 1983.* Melbourne, Australia.

Moritz, M. a, Batllori, E., Bradstock, R. a, Gill, a M., Handmer, J., Hessburg, P. F., Leonard, J., Mccaffrey, S., Odion, D. C., Schoennagel, T., & Syphard, A. D. (2014). Learning to coexist with wildfire. *Nature*, *515*(7525), 58–66.

Mutch, R., Rogers, M., Stephens, S., & Gill, A. (2011). Protecting Lives and Property in the Wildland–Urban Interface: Communities in Montana and Southern California Adopt Australian Paradigm. *Fire Technology*, *47*(2), 357–377.

Nadimpalli, N., Edwards, M., & Mullaly, D. (2007). National Exposure Information System (NEXIS) For Australia: Risk Assessment Opportunities . *MODSIM 2007 International Congress on Modelling and SimulationModelling and Simulation Society of Australia and New Zealand*. Oxley L and Kulasiri D.

Newnham, G., Blanchi, R., Leonard, J., Opie, K., & Siggins, A. (2014). *Bushfire Decision Support Toolbox Radiant Heat Flux Modelling: Case Study Three, 2013 Springwood Fire, New South Wales*. Melbourne.

O'Neill, S. J., Handmer, J., & Killalea, D. (2010). *Review of fatalities in the February 7, 2009, bushfires. Prepared for the Victorian Bushfires Royal Commission* . Melbourne: Centre for Risk and Community Safety RMIT University, Bushfire CRC.

Paveglio, T. B., Carroll, M. S., & Jakes, P. J. (2010). Adoption and perceptions of shelter-in-place in Californias Rancho Santa Fe Fire Protection District. *International Journal of Wildland Fire*, *19*(6), 677–688.

Paveglio, T., Carroll, M. S., & Jakes, P. J. (2008). Alternatives to evacuation - Protecting public safety during wildland fire. *Journal of Forestry*.

Penman, T., Eriksen, C., Blanchi, R., Chladil, M., Gill, A., Haynes, K., Leonard, J., McLennan, J., & Bradstock, R. (2013). Defining adequate means of residents to prepare property for protection from wildfire. *International Journal of Disaster Risk Reduction*, *6*, 67–77.

Prior, T. D. (2010). *Householder bushfire preparation: decision-making and the implications for risk communication*. University of Tasmania, Hobart.

Ramsay McArthur, N.A. Dowling, V.P., G. C. (1987). Preliminary results from an examination of house survival in the 16 February 1983 bushfires in Australia. *Fire and Materials*, *11*, 49–51.

Ramsay, G. C., McArthur, N. A., & Dowling, V. P. (1986). Building survival in bushfires. *Fire Science'86. The 4th Autralian National Biennial Conference*. 21-24 October, Perth.

Reisen, F. (2011). *Inventory of major materials present in and around houses and their combustion emission products*. Melbourne.

Reisen, F., Bhujel, M., & Leonard, J. (2014). Particle and volatile organic emissions from the combustion of a range of building and furnishing materials using a cone calorimeter. *Fire Safety Journal*, *69*, 76–88.

Rhodes, A. (2005). *Stay or go: what do people think of the choice?* Melbourne, Australia.

Rhodes, A. (2011). Opinion: ready or not? Can community education increase householder preparedness for bushfire? *The Australian Journal of Emergency Management*, *26*(2), 6–10.

Rubin, H. J., & Rubin, I. S. (2005). *Qualitative interviewing: the art of hearing data. Second edition*. Thousand Oaks: Sage Publications.

Scanlon, J. (1992). *Evacuations and Shelter. Disaster Preparedness: Some Myths and Misconceptions.* Easingwold, UK.

Scanlon, J. (1997). Human Behaviour in Disaster: The Relevance of Gender. *Australian Journal of Emergency Management, The*, *16*(1), 2–7.

Shepherd, P., & Sime, J. D. (1998). *Occupant Response Shelter Evacuation Model*. (U. Executive, Health & Safety Contract Research Report 162/199, Electrowatt Engineering and Jonathan Sime Associates, HSE Books, Sudbury, Ed.). Sunbury, UK.

Siggins, A., Leonard, J., Newnham, G., Blanchi, R., Lipkin, F., Opie, K., & Culvenor, D. (2013). *Modelling Radiant Heat Exposure at the Urban Fringe - Pine Ridge Road, Kinglake West, Case Study*.

Standards Australia. (2009). *AS 3959-2009 (Amend. 1) Construction of buildings in bushfire prone areas*. Standards Australia.

Stanley, P. (2013). *Black Saturday at Steels Creek*. Australia: Scribe Publications.

Stephens, S. L., Adams, M. A., Handmer, J., Kearns, F. R., Leicester, B., Leonard, J., & Moritz, M. A. (2009). Urban-wildland fires: how California and other regions of the US can learn from Australia. *Environmental Research Letters*, *4*(1).

Suzanne L . Furby , Peter A . Caccetta , Jeremy F . Wallace, E. a . L. and K. Z. (2009). Recent Development in Vegetation Monitoring Products From Australia ' S National Carbon Accounting System. *Internaitonal Geoscience and Remote Sensing Symposium*, 276–279.

Teague, B., McLeod, R., & Pascoe, S. (2010). *2009 Victorian Bushfires Royal Commission final report: summary. (State Government of Victoria: Melbourne)*.

Tibbits, A., Handmer, J., Haynes, K., Lowe, T., & J., W. (2008). Prepare, stay and defend or leave early: evidence for the Australian approach. . In Handmer Haynes, K. (eds) (Ed.), *In Community bushfire safety* (pp. 59–71). Melbourne: CSIRO publishing.

Tibbits, A., & Whittaker, J. (2007). Stay and defend or leave early: Policy problems and experiences during the 2003 Victorian bushfires. *Environmental Hazards*, *7*(4), 283–290.

Whittaker, J., Eriksen, C., & Haynes, K. (2015). Gendered Responses to the 2009 Black Saturday Bushfires in Victoria, Australia. *Geographical Research*, n/a–n/a.

Whittaker, J., & Handmer, J. (2010). Community bushfire safety: a review of post-Black Saturday research. *The Australian Journal of Emergency Management*, *25*, 7–13.

Whittaker, J., Haynes, K., Handmer, J., & McLennan, J. (2013). Community safety during the 2009 Australian 'Black Saturday' bushfires: an analysis of household preparedness and response. *International Journal of Wildland Fire*, *22*(6), 841–849.

Whittaker, J., Haynes, K., McLennan, J., Handmer, J., Towers, B., & CRC, B. (2010). *Report on Human Behaviour & Community Safety Issues. Mail Survey Victorian 09 Fires*. (Bushfire CRC, Ed.).

Whittaker, J., McLennan, J., Elliot, G., Gilbert, J., Handmer, J., Haynes, K., & Cowlishaw, S. (2009). *Victorian 2009 Bushfire Research Response: final report. (Bushfire CRC: Melbourne)*.

Wilson, A. A. G., & Ferguson, I. S. (1984). Fight or flee : a case study of the Mount Macedon bushfire. *Aust. For.*, *47*(4), 203–236.

Wilson, A. A. G., & Ferguson, I. S. (1986). Predicting the probability of house survival during bushfires. *Journal of Environmental Management*, *23*, 259–270.

Without Warning: One Woman's Story Of Surviving Black Saturday by Jane O'Connor — Reviews, Discussion, Bookclubs, Lists. (n.d.).

Xanthopoulos, G., Viegas, D. X., & Caballero, D. (2009). Recent Forest Fire Related Accidents in Europe. In Viegas (Ed.), *Recent Forest Fire Related Accidents in Europe* (European C). European Commission Joint Research Centre Institute for Environment and Sustainability.

Yard, C. R. (2000). Evacuation vs. shelter-in-place, a situational comparison. *Disaster Recovery Journal*, *13*(3), 28–31.

Zachria, A., & Patel, B. (2006). Deaths related to hurricane Rita and mass evacuations. *Chest Journal (American College of Chest Physicians)*.

11 Appendix 1: Coding framework

The coding developed for this project relates to information on types of shelter and activities while sheltering. Information was collected for a number of variables:

- Incident ID
- The people involved in sheltering.
- Residential address
- Shelter address
- Area (suburb)
- Both intentions and actions were recorded as free text. In addition, a distinction was made between active and inactive behaviour. Active sheltering behaviour was characterised by some monitoring of the fire or actions to protect the shelter and occupants. Conversely, inactive shelter behaviour was characterised by a lack of monitoring and actions to protect the shelter and occupants.
- House actively defended?
    - Yes
    - No
    - Unknown
- Presence of active shelterer(s)
    - Yes
    - No
    - Unknown
- Number active
- Presence of inactive shelterer(s)
    - Yes
    - No
    - Unknown
- Number inactive
- Location/s
    - In house
    - In building (e.g. school, hotel, pub etc.)
    - In other structure (shed, bunker, cellar, water tank)
    - Outside in open space
    - Outside behind a physical barrier
    - Water body (dam, swimming pool etc.)
    - In car/vehicles
    - Unknown
    - NA
- Where shelter/fatality location (detail location, If known as where in the house or precise location)
- Number of sheltering locations (if multiple places of shelter were used, then each of the locations and types of shelter)
- Number of people sheltering (total)
- Shelter survival. Whether the shelter survived was recorded for each incident and for each shelter
    - Yes
    - No
    - NA

- Residential address Status (destroyed / survived)
- Shelter ignited (yes/no)

- The survival of the shelter. Whether the shelter survived was recorded for each incident and for each shelter (yes/no/NA).
- The final status of a location in term of fire impact (if data available). In each case these were categorised into:
    - destroyed
    - damaged
    - untouched.
    - Additional information on house construction and defence. This information was recorded as free text in order to provide additional context regarding house vulnerability to fire exposure and the influence of occupant behaviour if the house survived.

12 Appendix 2 Additional accounts

Additional accounts from survivors that experienced house failure:

> *It was either stay in the house and certainly die or go outside and maybe probably die, but at least we had a chance. I knew that if we could get to the car, that would provide some shelter, so in the end that's what we did. We made the run from the house through the radiant heat and the embers to the car … that was enough for me to get burns on the back of my hand on the side that was facing the embers and the radiant heat. I got the car going and put the air-conditioning on, which again is what they advise you to do…. so initially we sat where we were outside the house. Then the house itself started to really take off and the roofing iron began to lift … So we then took the risk. I knew that just beyond those trees at the start of the paddock, at the top of our driveway, the fire must have already been through there and that would have been burnt out. I knew that was our best option, so we pushed through some of those burning fallen trees and got to that spot and stayed there.* (St Andrews)

> *The CFA advised that it normally took a fire front five to ten minutes to pass and then it was safe to go out and you could start putting out any spot fires that were there, but it became clear after much less than ten minutes, not much less, after about eight minutes or so, that the house was already on fire, much to our amazement and was starting to fill with smoke … so there was no way we could get any water on the fire, …. because we obviously had to evacuate the house.* (St Andrews)

> *Once the fire reached our house, the building started to burn immediately. [Name removed] and I spent about ten minutes attempting to fight the fire. … We also had gas ducted heating at our house and at about the same time that the gas cylinder exploded, … It became apparent that flame was engulfing the underside of our house. After the back windows blew in, I yelled at [Name removed] and told her to "get out". We both ran for our lives and jumped out of the house and got into the car. The flames seemed to follow us as we ran. If the car was locked, we would have had nowhere else to shelter from the fire and the radiant heat and I am certain that we would have died.* (Marysville)

> *It got to the point where I had to retreat inside because the radiant heat was burning my face and neck. I went to check the upstairs part of the house and it was then that I first noticed that the dormer window had caught on fire. I estimated that it would probably be another 10-20 minutes before the roof would collapse. …We waited until the house next door had finished burning and then I went outside to get the car ready… and then the seven of us all got into the car and evacuated. We drove to the oval at Gallipoli Park which I had always planned as being our evacuation point.* (Marysville)

> *I used my house initially to shelter from the flames and I then escaped before my house was destroyed by the fires.* (Kinglake)

Additional account on future plans:

> *You say the general plan is to activate sprinkler system and get into fire shelter. Does that really summarise the lessons that you have taken out of 7 February about what is really important to do to survive?---That page I produced myself to try and give people a realistic idea of what you can be up against. The number one thing that I promote to all people I come in contact with is the best plan, the best strategy to survive a wildfire, is to not be there, is to get out, is to go, is to leave if you*

can do so safely - if - and that's the decision that people have to make and it can be a hard decision to make. On a 30-plus degree hot summer's day you are physically and mentally lethargic. On a 45-plus degree extreme heat summer's day your decision-making process is compromised. If one person reads that page and changes their plan to leaving early, it's done its job. But if people can't leave - and there are a lot of reasons why people can't leave; they haven't got family to go to or friends that they can go to, it doesn't fit their lifestyle - well, that's giving people a realistic idea of what you can be up against and if you want to be prepared, well, you know, a sprinkler system over your whole house and a fire shelter that you can retreat to is what I say is being fully prepared. (Kinglake)

If I had a bunker, something I knew that could take it, I'd just walk, cruise on down to the bunker, and just relax and just wait for it. (Heathcote Junction)

So I think in the future there should be a communal bunker that can hold us all, or a few of them, or have one of your own, have one yourself. (Marysville)

I would like to rebuild … Maybe this time [I would] rebuild a house that was much more fire-safe, and for the safety of the residents I suppose I would put a little bunker or something where they can hide, some sort of fire protection, [so] that they don't have to leave. (Strathewen)

If you set yourself up a fire bunker, you can start it all up, go in your bunker, wait one hour, and come back out again. (Hazeldene)

13 Appendix 3 Statistical analysis

Table 16 The highest scoring metrics in the assessment of individual variables on the probability of success of survival sheltering

Data	Coefficient estimate	Standard error	z value	Pr(>|z|)	AIC	Fisher	Null Deviance	Residual deviance	Null Degrees of freedom	Residual Degrees of freedom
Number of active people sheltering	0.80	0.141	5.66	1.50E-08	461	5	500	457	493	492
Number of people sheltering	0.47	0.111	4.25	2.14E-05	478	6	500	474	493	492
Shelter location number	-0.64	0.182	-3.53	0.000412	492	4	500	488	493	492
Fire severity (Kilmore East only)	0.18	0.053	3.38	0.000715	492	4	500	488	493	492
Within forest	-0.68	0.225	-3.02	0.002552	495	4	500	491	493	492
Distance to forest	0.01	0.004	2.42	0.015496	495	5	500	491	493	492
Residence at a residential Building	0.75	0.445	1.68	0.093665	494	4	500	488	493	491

Table 17 The pseudo r^2 of the most significant predictors of successful survival in a shelter

Data	Log likelihood	Log likelihood for null model	Minus two times the difference in the log-likelihoods	McFadden's pseudo r^2	Maximum likelihood pseudo r^2	Cragg and Uhler's pseudo r^2
Number of active people sheltering	-228.54	-250.22	43.36	0.09	0.08	0.13
Number of people sheltering	-236.80	-250.22	26.85	0.05	0.05	0.08
Residence at a residential building	-243.79	-250.22	12.86	0.03	0.03	0.04
Shelter location number	-243.81	-250.22	12.81	0.03	0.03	0.04
Fire severity (Kilmore East only)	-243.92	-250.22	12.60	0.03	0.03	0.04
Not within forest	-245.66	-250.22	9.11	0.02	0.02	0.03

Distance to Forest	-245.73	-250.22	8.97	0.02	0.02	0.03