



Victorian 2009 Bushfire

Research Response

Final Report

October 2009

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The research response to the 2009 Victorian Bushfires was initiated on Monday 9th February, less than 48 hours after the onset of the events that devastated many communities across Victoria and have had a lasting impact on individuals, the industry and the State. We acknowledge the foresight of the leaders of the Victorian agencies in initiating this work, which will help to ensure the learnings from this event are captured in the hope that this will help us better understand such events into the future.

This Research Response Taskforce was led by a team of skilled researchers from around Australia, NZ and the USA with a strong track record of expertise in understanding bushfire and its impacts.

Researchers were supported by a large number of trained field staff from fire agencies across Australia and New Zealand, many of whom spent considerable time away from their family and their usual tasks to contribute to this work. In addition, many people contributed to the research, through the provision of equipment or support in the field, in logistics, intellectual support, leadership and countless other ways. Our sincere thanks are due to all who worked in our teams or who collaborated with us. We particularly thank the agencies and organisations that have made staff members available at either ‘in-kind’ or substantially reduced rates to contribute to this work. We also would like to acknowledge the peer reviewers who kindly donated their time Dr Paula Beaver; Dr William (Ruddy) Mell and Mr Jim Gould.

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National Aerial Fire Fighting Centre	New South Wales Fire Brigades	New South Wales Rural Fire Service
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EXECUTIVE SUMMARY

The devastating Victorian bushfires of 7th February 2009 resulted in major loss of life, property, and other assets. They will be the subject of major debate for years to come. Indeed, the establishing of the 2009 Victorian Bushfires Royal Commission will help ensure that the key issues are considered. In developing directions for the future, it is vital that these are based upon solid evidence of what happened and why. Many agencies and organisations have been examining elements of these issues. However, to do this thoroughly, a major research effort was required to establish an authoritative and independent data set for the Australian and international fire community. It must be stressed that little detailed analysis has been conducted on these data sets to date.

This report sets out the establishment of the data set, and partial findings from the extensive study undertaken.

On 8th February, the Bushfire CRC was asked to establish a research taskforce to undertake the biggest data collection and analysis program ever undertaken in the aftermath of a bushfire disaster in Australia, and quite probably anywhere. Every day over a period of nearly two and half months, the Bushfire CRC placed teams of up to 50 researchers from across Australia, NZ and the USA in the field. This amounted to more than 2000 staff days of extensive data collection and analysis. This analysis has focussed on the Bunyip, Kilmore, Murrindindi, Churchill, and Bendigo (Maiden Gully) fires.

The intent of the work was to collect time-critical data that would rapidly degrade because of weather, site clearance or other interference. This data is capable of answering various questions relating to the fire behaviour, human behaviour, and house survival or destruction.

This report contains five major chapters that outline the data collected in the various areas, as well as draw some preliminary conclusions and findings from this data. These four chapters have been authored by the lead researchers in each area. While the Bushfire CRC has provided oversight on the reports, the content remains that created by these authors.

The authors of each have drawn their findings from the individual data sets and have not had the opportunity to cross-reference to the other data sets. The analysis has also not been systematically cross-referenced to any recent evidence presented to the Royal Commission.

DIFFERENCES BETWEEN INTERIM AND FINAL REPORT

This final report is compiled as a standalone document and should replace the interim report issued in June 2009. Therefore much of the content of the Interim report is repeated in this report. In order to remove any confusion the Fire Behaviour and Demographic reports are unchanged from the Interim Report.

The Human Behaviour report has been substantially rewritten to reflect the analysis of 50% of the interviews. This further analysis has reinforced the findings outlined in the interim report.

The Buildings and Land Use Planning report has been updated with the results having been validated and broad changes made to improve readability. No new findings are presented over and above the interim report. In between the issuing of the interim report in June and the delivery of this final report under the contract with the Victorian Agencies, there have been a number of key pieces of work conducted this has included preparation and presentation by Mr Justin Leonard of the work considered in the Building Chapter of this report to the Royal Commission. Mr Leonard's transcript from the Royal Commission in relation to this work is attached to the back of the building report

The Integrative studies covering Kinglake (Reserve/Victoria Roads and Pine Ridge Road); Strathewen and Marysville have been added to this report.

DATA MANAGEMENT

The data sets created have now been effectively validated, with help of an information management expert from the Office of the Emergency Services Commissioner. This has included extensive analysis of the various crew location data, and effectively geo-coding of the data.

The data is now geo-spatially tagged so that each of the three team's data can be overlaid on a GIS system this illustrated for a portion of Marysville in Figure 1. Similar overlays can be produced for other areas surveyed.



FIGURE 1: A DATA OVERLAY SHOWING A PORTION OF MARYSVILLE (BLUE ARROWS FROM THE FIRE BEHAVIOUR TEAM; YELLOW DOTS INTERVIEW LOCATIONS; ALL OTHER SYMBOLS ARE ELEMENTS FROM THE BUILDING ASSESSMENTS)

POSTAL SURVEY

The proposed postal survey was sent out during the week of 12 October and has been widely published through the Bushfire CRC website, through a press release, and interviews with ABC local radio in Bendigo, Gippsland and with ABC 774. It is intended that the detailed analysis of the mail-out survey will be supplied at a later date depending upon the response rate to the survey. The survey has been distributed to around 6000 households in the fire affected areas of Kilmore East, Murrindindi, Churchill, Horsham, Bendigo, and Beechworth.

The key questions being addressed by the survey relate to:

- How were people in different areas of the state affected by the fires?
- How was the "Prepare, Stay and Defend or Leave Early" policy understood and used in fire prone communities on February 7?
- What did people do to protect themselves and their property before and during the fires?
- Were fire warnings adequate?
- How could warning systems be improved?

INTRODUCTION

BACKGROUND TO THE RESEARCH

On Saturday 7th February 2009, Victoria experienced Australia's worst bushfires in recorded history, resulting in over 2000 homes lost and significant loss of life.

In response to these events, the Bushfire Cooperative Research Centre (Bushfire CRC) established a Research Taskforce (the Taskforce) to collect the data that would subsequently be needed to underpin major research for the Fire and Land Management sector and the research community in Australia and overseas. The initial scope of work for the Taskforce covered the areas of Fire Behaviour; Human Behaviour and Community Safety Issues; Building (Infrastructure) and Land-Use Planning, and was set out at a high level between the Bushfire CRC and key stakeholders the Country Fire Authority (CFA), Department of Sustainability and Environment (DSE) and the Office of the Emergency Services Commissioner (OESC) and agreed on Wednesday 11th February, only four days after the fires started and while a number were still to be contained.

At the request of the key stakeholders, the research efforts focussed on five major fire complexes: Kilmore, Murrindindi, Churchill, Bendigo and Bunyip. Within these large fire complexes, smaller study areas were identified to reflect the major areas of community impact (loss of life and property) along with the different types of fire behaviour and fuel levels exhibited on the day.

Having agreed on this broad scope of work, the research specifically undertaken as part of this initiative focussed on the collection of data to underpin the understanding of the following:

- the fire behaviour exhibited across the major Victorian fire complexes on 7th February 2009;
- the human behavioural factors that impacted upon the patterns of property or life loss or saves during these fires;
- the building and land-use planning factors in the nominated areas that contributed to the pattern of property or life loss (or saves) during these fires; and
- the way in which these factors worked collectively to impact on the pattern of loss of life and property.

All aspects of the work considered the question: 'Was the impact of the fires of 7th February 2009 consistent with established knowledge or was this a result of previously unidentified behaviours or factors?'

The Research Response Taskforce was led by team of skilled researchers from around Australia, NZ and the USA with a strong track record of expertise in understanding bushfire and its impacts. These researchers, supported by a large number of trained field staff from fire agencies across Australia, gathered and collated as much information as possible in a time-critical period to ensure that this information was available for the longer-term research needs of the industry and to begin the lessons-learnt process.

OVERVIEW OF THE REPORT AND RESEARCH APPROACH

This document is the final report on the outcomes of this work and has been provided to enable stakeholders to consider the matters identified by the researchers as part of the material available to inform the 2009 Victorian Bushfires Royal Commission. This report is supported by a substantial database of scientific observations, photographs and interviews collected by the research Taskforce and provided to the Victorian agencies.

The main body of the report is made up of four chapters each covering one of the areas of investigation. These chapters have been written as 'stand-alone' documents by the individual research teams, with appendices covering details of the database, data management and supplementary information provided by the authors. While the specific research methodologies vary depending on the particular subject matter area, the broad research approach is consistent across the themes – that is, the researchers followed the steps identified below:

- Observation (data collection),
- Analysis,
- Identification of patterns and trends, and
- Consideration of existing models and assumptions.

Details of the research method adopted and individual research questions in each of the thematic (project) areas are provided in the specific chapters of this report.

The report is structured as follows:

An overview and context for the study. It includes a summary of findings, the current introduction, and understanding of the scope and limitations of the work, and identifies further work to be undertaken to complete Phase 1 of the project as agreed with the key stakeholders.

Chapter One covers the area of fire investigation. The key part of this work was the collection and documentation of *in situ* leaf freeze angle data that when added to other data sources can be used to reconstruct the passage of the fire. This chapter and the accompanying maps do not in themselves provide information on the direction of spread of the fire but rather provide the visual clues and scientific underpinning that, combined with the other data sources, will be able to support such analysis.

The data described in this chapter is supported by a large number of images that have been linked to the field observations in a geospatially referenced database.

This chapter also provides important information to assist in understanding the events of 7th February in the context of other significant bushfire events in Victoria.

Chapter Two covers the area of human behaviour and community safety. This chapter includes discussion (and preliminary analysis) of the semi-structured interviews conducted with residents in affected areas in the weeks following the fires. It is important to note that while more than 600 interviews were conducted (and have now been transcribed); the analysis presented here is based on approximately 200 of these using key words based on the areas of interest identified in the project documentation. All interviews have been geospatially referenced and demographic data on respondents collected to enable more detailed investigation and segmented analysis as required.

The work on human behaviour will be supplemented by a mail-out survey, which will be reported upon in a later report.

Chapter Three covers the area of building and land-use planning. As part of the data collection exercise, researchers undertook a detailed survey of a sample of buildings in the fire-affected areas. The aim of this was to better understand the factors impacting on the patterns of loss and survival. Survey questions cover building design and construction materials, along with the degree and cause of damage. In total, more than 1000 properties were surveyed; this data has been collated into a geospatial-referenced database that will be available to the agencies.

Work in this section is supplemented by the use of remote-sensing imaging to provide an understanding of the terrain and the structure of the surrounding vegetation. The chapter provides a preliminary analysis of this data covering the areas of primary interest.

Chapter Four is an analysis of the socio-demographic characteristics of the residents of the areas based upon the analysis of census data.

Chapter Five provides integrative studies. These studies show how the work of each of the research teams can be brought together to understand the interplay between fire behaviour, human behaviour, building and housing loss. At the time of writing, these integrative studies have been based on site inspection and discussion of the key data sets. However, they have not had the benefit of rigorous interrogation of the consolidated data set, which we expect to uncover substantial new learnings.

The reporting of each of the thematic areas covered in this report has been subject to review by independent researchers with subject matter expertise in the relevant area. In each case, these reviewers have advised that the methodology applied and the data collection is consistent with good scientific practice in that discipline. They have also provided feedback to the researchers on any areas where they felt that the conclusions that had been drawn could not reasonably be drawn from the information presented. We are grateful to these independent experts and acknowledge their contribution to improving the outcomes of this work.

LIMITATIONS

It is important to recognize that this work was commissioned principally as a data-collection exercise to ensure that data that could be destroyed by time or human intervention was not lost in the aftermath of the fires. Further to this, the analysis provided here has been based on information collected by the Bushfire CRC research Taskforce only. This was not the only data collected in this period and much of this supplementary data will have information that could add further depth to the analysis in each of the sections. Specifically, this Taskforce has not had access to observational logs of fire service personnel or material collected by other agencies (most notably police fatality information and the Rapid Impact Assessment facilitated by the Office of the Emergency Services on behalf of the response agencies) or the detailed (post-event) weather reports collated by the Bureau of Meteorology. There is also a wealth of information available via various web pages that provide first-hand reports and visual images of fire behaviour and impacts in a variety of locations that can be interrogated in future work.

Data collection in some areas was limited owing to access constraints. Researchers were not sent into areas where the fire was still active (and indeed were withdrawn from the field on the weekend of 14th–15th February when the bushfire danger was once again expected to be extreme). Researchers were also excluded from areas that were identified as fatality scenes or were the subject of criminal investigations. Access to other areas was also constrained until they were opened to the residents. This particularly restricted data collection in the Marysville area during February.

Further to this, owing to the timing required of this report, it has not been possible to analyse all of the data collected or to undertake the depth of analysis usually undertaken in such a study. It is particularly important to note that owing to the scale of the events and the time-frames available, this report cannot provide detailed investigation of any individual event, location, or structure but rather considers the patterns evident as a result of these events.

In this context, as noted above only a sample of the interviews conducted has been analysed and the full depth of the information collected in this manner has not been explored. Similarly, while some first integrative studies have been undertaken, these are based on the review of the information available and the expert knowledge of the researchers rather than by combining the data sets from each of the survey times.

It is also important to note that at the time of writing, the outcomes of the mail-out survey (to be conducted as part of the Human Behaviour theme) are not available. These will be provided in a supplementary document. Details of the information collected by each of the teams are included in the relevant chapters of this report.

In summary, the findings outlined in this report should be considered as preliminary based on the best available information at the time. They may be subject to amendment as additional information becomes available. Notwithstanding this, the Bushfire CRC is confident that the information presented here has the benefit of robust data, sound scientific knowledge (based on the experience of the research leaders) and can provide insights that are valuable in understanding the factors contributing to the 7th February bushfires in Victoria.

FIRE NAMING CONVENTIONS

There have been a number of names attributed to the various fires during the course of the control activities. In order to avoid confusion, this report follows the following conventions. The table below shows the names of each fire for the DSE and CFA. The CFA have divided the Kilmore East and Murrindindi fires; however the DSE combines these into a complex divided by north–south terminology.

CRC Fire name	CFA	DSE
Churchill	Churchill	Churchill–Jeeralang
Bunyip	Bunyip	Bunyip Sp–Bunyip Ridge Track
Bendigo/Maiden Gully	Maiden Gully	Eaglehawk–Bracewell Street
Kilmore	Kilmore East	Kilmore East–Murrindindi Complex South Kilmore East–Murrindindi Complex North
Murrindindi/Yea	Murrindindi	

SUMMARY FINDINGS

FIRE BEHAVIOUR

Bushfire behaviour covers everything a bushfire does – it includes the way a bushfire ignites, develops and grows its rate of spread, the characteristics of the flame front and all other phenomena associated with the moving fire. The key problem with understanding bushfire behaviour is that it involves a complex chemical reaction (combustion) moving through a fuel bed that varies in three dimensions across a variable topography and interacting with a turbulent atmosphere (principally wind) that varies widely in space and time.

The fire behaviour chapter summarises data collected by the Fire Behaviour Investigation Team. The objective of the field-work was to collect data from fire spread indicators that could, in conjunction with other information about the time and location of the bushfires, be used to reconstruct the passage of the fires. Emphasis was given to collecting information from sources that would degrade rapidly or be lost forever with the passage of time following the fires. Fuel hazard assessments were based on the Victorian Overall Fuel Hazard Guide (McCarthy *et al.* 1999) and the Project Vesta Field Guide: Fuel Assessment and Fire Behaviour Prediction in Dry Eucalypt Forest (Gould *et al.* 2007b).

PREVAILING AND HISTORIC WEATHER CONDITIONS

Weather data obtained from the Bureau of Meteorology has also been presented to provide a context for conditions prior to and on the day of the fires.

The cumulative effect of the successive years of below-normal rainfall in the decade prior to 2009 is likely to have significantly affected groundwater levels, soil moisture and the dryness of large dead woody fuels such as stumps and fallen logs. Data from the Bureau of Meteorology showed that on 7th February 2009, the measures of drought and fuel dryness for some localised areas in the Yarra Valley were up to 50% below the normal levels expected at that time of year. Grassland-curing maps prepared from NOAA satellite imagery showed that by 7th February 2009, in the grasslands and pastures in the Upper Plenty Valley, Yarra Valley, eastern parts of the Goulburn Valley and Gippsland ranged from 65% to >95%. At the same time areas to the north and west of the state were approaching full curing (>95%).

Simulations suggest that owing to the very hot and dry conditions, the moisture content of the fine fuels was extremely low, resulting in high combustibility and increased available fuels. The very low overnight moisture content of the night of 6th February meant that, with the onset of hot dry conditions on the morning of 7th February, there was little moisture in the available fuel.

The initial focus for the data collection was to obtain data that could be used to determine the location of the north-eastern flank of each fire prior to the wind change.

FINDINGS BY FIRE COMPLEX

This report provides a description of key elements of the Bunyip, Kilmore, Bendigo, Churchill, and Murrindindi fires. Data has been organised and presented in a spatial context that will allow it to be linked to sources of information from other investigations undertaken by the Bushfire CRC Taskforce, information held by CFA, DSE and other agencies, and observations made by eyewitnesses to the events.

Findings from this work will arise as the data is combined with other data sets derived through the CFA and DSE in future work. Notwithstanding this, the following observations can be made:

- **Bunyip** This fire was reported to have first started on the early evening of 4th February at 1700 hrs. Over the next two days, the fire extent increased to approximately 170 ha. At some time early on the morning of 7th February, the fire broke containment lines constructed during the preceding days and travelled in a generally SE direction along timbered ranges for about 7 km and into adjoining farmland.

Farmland was mainly pasture with a mix of dry dairy, grazing and meadow hay in a wide range of curing conditions depending on species and management practices. Windbreaks, roadside reserves and riparian areas along the Labertouche Creek were dominated by mealy stringy bark, also common in the farming landscape. Much of this remnant bushland was fully crown-scorched or in some places defoliated by crown fire, even those remnants located within otherwise unburnt paddocks. Within the extent of burnt area in farmland, Landsat images taken on 17th February show as much as half the area unburnt. It was difficult to determine if farmland areas were unburnt owing to low curing or suppression efforts.

Topography appears to have strongly influenced fire behaviour following the wind change. On lee slopes away from the prevailing wind, the inferred direction of fire spread sometimes differed to the prevailing wind. Spot fires, or congregations of spots, were observed in at least four locations on line-scan imagery at distances of 8 and 10 km from the head fire and forest edge respectively. Burnt area associated with these spots was as large as 100 ha.

The extent of crown scorch and defoliation evident in satellite imagery appeared to be considerably reduced in the area burnt in a 2004 wildfire and a 2005 prescribed burn, suggesting lower fire intensity in these areas. This observation warrants a more systematic evaluation with supplementary field assessment and analysis of high-resolution air photography.

- **Kilmore** The point of origin of the fire was in the Saunders Road area near Kilmore East and the general direction of fire spread was initially to the SE through pasture and radiata pine plantation. The fire crossed the Hume Highway north of Wandong, skirting the northern edge of the town and the SE along the escarpment of the Hume Range, which becomes increasingly rugged and broken east of Humevale. Following the south-westerly wind change, the NE flank of the fire moved on a broad front through forested country on the Hume plateau and mixed agricultural lands extending between Kinglake West and Kinglake. The final perimeter reached just north of Flowerdale, Break O'Day and Glenburn.

Fire spread indicators revealed a number of important characteristics of the Kilmore fire as follows:

- the fire had a very elongated shape under the influence of north-westerly winds, with a length to breadth ratio of about 7:1;

- under the influence of north-westerly winds, the fire passed to the south of Kinglake West and did not impact on this community until after the south-westerly wind change;
 - patterns of fire spread became increasingly complex east of Humevale with fire spread indicators consistent with a head fire running under north-westerly winds and fire runs from the south or south-west associated with the wind change and localised terrain effects. This may have extended the period of time over which residents of ridge-top settlements and farms were subject to severe fire behaviour and led to uncertainty about which direction the fire was approaching from;
 - the Strathewen area appears to have been impacted by fire running on a north-westerly wind and also by a major fire front approaching from the south;
 - much of the area north of the road between Pheasant Creek and Kinglake remained unburnt because of cultivated paddocks or incompletely cured pasture;
 - a number of areas burnt since 1995 had reduced levels of canopy scorch or had not burnt at all, suggesting that fire intensity was reduced because of younger fuels;
 - despite the dry conditions experienced in January 2009, green grass was observed in some paddocks on the Kinglake plateau, and fire did not spread continuously across these paddocks in spite of extensive spotting.
- **Bendigo** Fire spread indicators for this area are consistent with fire spreading under north-westerly winds from the point of origin, at least to the stage where the fire crossed the road between West Bendigo and Long Gully; on the eastern side of this road, indicators are mostly consistent with winds from a south-westerly direction. The section of the north-east flank of the fire that burnt through the locality of California Gully was associated with indicators of spread under south-westerly winds, as were a number of smaller burnt areas around Eaglehawk and Long Gully, which could have been ignited by spotting following the south-westerly change.
 - **Churchill** Ignition points for this fire were on the southern side of Glen Donald Road, 3 km SE of the town of Churchill. Smoke was detected at 1335 hrs, with fires reportedly ignited in roadside grass, but rapidly spreading uphill into a 15-year-old blue gum plantation, intensifying and crossing Jelleff's Outlet Road under the influence of strong NW winds. The fire continued spreading SE, pushed by the NW winds and aided by positive slopes, which took the fire into complex terrain within the Strzelecki Ranges. The SE run ended near Balook (~15 km from ignition point) probably owing to the arrival of the wind change.

Apart from post-harvest residue burning, fire has largely been excluded from forested areas within the fire perimeter since 1939. As the forest is productive and receives reliable high rainfall, there has been very considerable build-up of fuel during this period. Grasses were less than 60% cured in many parts, particularly at the bottom of valleys and creek lines.

Fire spread is likely to have involved substantial spotting as evidenced by the number of spot fires outside the final perimeter of the main fire. There were more of these than indicated on the official fire maps, though these tended to be much less intense than the main fire.

- **Murrundindi** The fire initially spread SE from a point of origin near Murrindindi Mill. The fire was narrow, with its eastern flank somewhere between the Murrindindi River and Black Range Rd. Evidence of spotting and NE spread near Bull Creek Rd suggests this was as far as the fire progressed in this direction before the wind change. After the wind change, the fire spread NE towards Marysville and the Goulburn Valley Highway.

Indicators in this area were mostly consistent with fire run under north-westerly winds, but in at least one place suggested up-slope fire spread contrary to the prevailing wind during this phase of the fire run. Indicators in and around Marysville were predominantly for south-westerly winds, although with some examples of fire spread direction apparently terrain-dominated. Based on the location of several observation points showing inferred south-westerly wind direction and the presence of linear patterns of scorched tree crowns, the width of the head fire burning under north-westerly winds appears to have been about 5 km, resulting in a length to breadth ratio of about 5:1.

SPOTTING

Spotting appears to have been an important means of fire spread on 7th February, facilitating fire spread from one ridge-top to the next in areas of broken terrain, and carrying the fire across areas of sparse eaten-out pasture or, at higher elevation, across areas where grass was less than fully cured and might otherwise have arrested fire spread. In situations where topography was broken, such as along the southern escarpment of the Hume Range, this capacity for significant lofting of firebrands translated into significant potential for massive short-distance (0–200 m) and medium-distance (200–1000 m) spotting.

In the case of the Churchill fire, the spread is likely to have involved substantial spotting as evidenced by the number of spot fires outside the final perimeter of the main fire. A number of long-distance spots from the initial fire run under north-westerly winds reached around 22 km from the main fire perimeter.

By way of comparison, spotting distances predicted by the McArthur Forest Fire Danger Meter (FFDM) range from 3.6 km for Bendigo to 11 km for the Kilmore East fire. Spotting distances predicted by the Project Vesta field guide range from 0.7 km for the Bendigo fire to between 6.5 and 7.4 km for the other fires, which is the highest value currently provided for in the tables.

COMPARISON WITH PREVIOUS FIRE EVENTS

The combination of prevailing and historical weather conditions is important as there is a strong association between drought and the occurrence of major bushfires in central and eastern Victoria. In Victoria, there have been a number of days in which the weather has resulted in disastrous wildfire conditions: Black Friday (13th January 1939), Western Districts (12th February 1977) and Ash Wednesday (16th February 1983). Of these, Black Friday provides the closest set of conditions for comparison with 7th February 2009. The 1977 Western Districts fires are unique here as they were predominantly grass fires and not associated with rainfall deficit. The Canberra fires of January 2003 occurred under slightly lower temperatures than 7th February, but where very low relative humidity's resulted in extremely dry fuels and very-high-intensity wildfire behaviour.

APPLICATION OF EXISTING MODELS

The project plan prepared for the Bushfire CRC Research Taskforce posed the question of whether the fires of 7th February 2009 behaved in a manner that was consistent with existing fire behaviour models. This is an important question as it relates directly to planning for emergency response, and also to the direction of future fire behaviour research in Australia.

Proper evaluation of the performance of existing fire behaviour prediction guides requires detailed reconstruction of the path of spread of each of the major fires using weather data,

fire spread direction indicators and reliable information about the position of the fire perimeter at various times during the day as each fire developed; information about the location of spot fires ahead of the main fire front is also required. The Bushfire CRC Fire Behaviour Team was not able to access time-specific observations of fire location during the preparation of this report and so a detailed reconstruction of fire spread is not presented here. However, to facilitate a preliminary evaluation of existing fire behaviour guides, information sourced from publicly available weather observations, maps, and eyewitness accounts of fire behaviour was used to determine the distance travelled and average rate of spread prior to the wind change on 7th February. No reliable information was available about the duration of run of the Bunyip fire and hence a rate of spread has not been determined.

- The Bendigo fire spread faster by a factor of two to three times than predicted by either the FFDM or the Project Vesta model, possibly because the very open nature of the forest at Bendigo resulted in higher wind speeds under the canopy than assumed by either model.
- The observed rate of spread of the Churchill fires was intermediate between the prediction from the FFDM and the Project Vesta model.
- The Kilmore East and Murrundindi fires spread two to three times faster than predicted by the FFDM, and up to 1.5 times faster than predicted by the Project Vesta model.
- Rates of spread observed on 7th February are within the range reported previously for eucalypt forest burning under extreme fire danger conditions on Ash Wednesday 1983 at Trentham and Deans Marsh (Rawson *et al.* 1983).

It needs to be recognized that these simple predictions make no allowance for the contribution of spotting to the spread of the fire, which is unlikely to be a valid assumption under the extreme fire danger conditions that prevailed on 7th February.

FINDINGS

The fire behaviour analysis can draw the following broad findings from the work carried out so far:

- Spotting ahead of the main fire front played a significant part in the forward rate of spread of all the fires.
- The current fire behaviour meters under predict the forward rate of spread seen on the day.
- Further work is required to understand the detailed progression of the fire across the landscape.

HUMAN BEHAVIOUR

This report has documented the findings of research into human behaviour and community safety issues during the bushfires of 7th February 2009. Findings relating to residents' planning and preparedness for the bushfires, information and warnings, intentions and actions, and emerging issues and themes have been presented. Owing to the timeframe for this Report, it was not possible to read and analyse all of the interview transcripts. The analysis detailed in this report is based on 301, or roughly one-half, of the interview transcripts. To summarise, the key findings of the preliminary analysis suggest the following:

PLANNING AND PREPAREDNESS

- Many residents were not prepared for the severity of the February 7th bushfires.
- Many interviewees living in more suburban locations had not planned or prepared for bushfires because they did not consider themselves at risk.
- A considerable amount of last-minute planning and preparation took place on the day.
- There are many examples of 'weak links' in people's planning and preparation that affected their ability to implement their fire plan.

INFORMATION AND WARNINGS

- Agencies such as the CFA and local councils had been only modestly successful in informing members of at-risk communities about effective preparation and planning for bushfires.
- Predictions in the preceding week were that Saturday 7th February was to be a day of unprecedented fire danger. There was only modest awareness of the implications of this in the community.
- The lack of timely information about developing threats to St Andrews, Strathewen, Kinglake, Kinglake West, Narbethong and Marysville may have contributed to many people being surprised by the sudden impact of the fire.
- Environmental cues such as smoke were important in alerting people to developing threats and in many instances prompted an active search for more information or a decision to leave or initiate defence.

INTENTIONS AND ACTIONS

- Half of the households represented in the interview sample reported at least one household member whose intention was to stay and defend. The perceived success of the 'stay and defend' strategy in past bushfires appears to have influenced people's intentions to stay and defend.
- A quarter of households in the interview sample reported at least one household member whose intention was to leave during a bushfire. Beliefs about the survivability of houses and their safety as a refuge during bushfires were paramount.
- A significant number of residents intended to wait and see what the bushfires were like before deciding whether to stay or go. These residents wanted to stay and

defend their homes and properties, but were not fully committed or confident in their ability to do so in all conditions.

- Approximately 10% of interviewees had not previously considered how they would respond to a bushfire. These residents typically lived in more suburban locations and did not consider themselves to be at risk from bushfires.
- Less than half (approx. 45%) of the households in the interview sample reported that a household member stayed to defend. Some of those who intended to stay and defend left because of the severe conditions.
- More than half (approx. 55%) of the households in the interview sample reported that a household member left because of the fires. There appear to have been many late evacuations.
- A very small number of interviewees sheltered passively throughout the fire.
- Some of those who stayed to defend may have exposed themselves to considerable danger by moving around fire-affected areas.

EMERGING ISSUES AND THEMES

- It appears that many residents endeavoured to return to their properties as soon as possible after the main fire danger has passed. There are many reasons for wanting to return, but the desire to check on the status of and defend property appears to be an important driver of behaviour.
- Many community members regarded public buildings, ovals and emergency services facilities as safe places of refuge during a bushfire. There is some evidence of support for purpose-built community shelters in which residents can take shelter during a bushfire.
- Some of those who stayed to defend their homes and properties reported a range of factors that influenced their capacity to defend. These included heat exhaustion, dehydration, breathing difficulties, and eye irritation. A range of pre-existing medical conditions, such as asthma and arthritis, also inhibited some people's capacity to defend.
- Anecdotal evidence suggests that many of those who sheltered passively inside their homes may have done so in bathrooms.

BUILDING AND PLANNING

A detailed dataset has been established that can assist further analysis for future planning and building codes reform. The opportunities of spatial data capture have only begun to be explored in the analysis of this dataset. From the preliminary analysis performed, the following conclusions can be made:

- Over 1000 houses have been surveyed to form a representative sample of houses lost in these fires.
- Active defence of structures has a major influence on house survival.
- Building quality, detail and possibly house age appear to be factors influencing the likelihood of house loss.
- Brick houses performed significantly better than mud brick and light-weight constructions clad with timber and cellulose cement sheet.

- The potential for wind damage of structures should be a key factor in future building consideration in bushfire-prone areas.
- Approximately 20% of house loss in the chosen study areas appears to be directly related to their immediate proximity to adjacent forest fuels.
- House loss has occurred at distances greater than 380 m from continuous forest, and this figure may be substantially greater once a broader set of houses is analysed.
- Over half of the surveyed houses lost in the February 7th fires were not in regions classified by a Wildfire Management Overlay.
- Metal and concrete water tanks are more likely to maintain an effective water supply for house defence than polyethylene and fibreglass tanks.
- Design, location and degree of protection of water pump and pipe-work are important factors in maintaining an effective water supply throughout the fire event.
- Mains water pressure and mains electricity cannot be relied upon during the fire event.
- Vegetation overhanging or immediately adjacent to houses, whether it is isolated or continuous, is a key factor influencing the likelihood of house loss.

DEMOGRAPHICS

This chapter has included a new indicator – the number of unoccupied homes – collected during the census and from the Australian Bureau of Statistics. The analysis of this indicator has shown that some of the areas affected by the bushfires of February 2009 had a significant number of unoccupied homes on census night. This measure indicates the number of second homes, that is, holiday homes or weekenders. While we can make some assumptions about the significance of this indicator, further work investigating the link between the number of unoccupied homes, fatalities and house loss is warranted. Marysville provides an opportunity to test this relationship, with a high number of fatalities, house losses and unoccupied homes.

FURTHER WORK

The work covered by this report is primarily to gather data. In the aftermath of the fires, there was a wide range of information collected by the Victorian agencies as part of the investigative and community recovery and restoration actions. As discussed above, some analysis has been conducted on these data sets. There are ongoing discussions for the ongoing analysis of the data collected by the Bushfire CRC Taskforce and the consolidation of this data with that collected by other.

It is now imperative that the various Government agencies consider what research is required in order to gather the learnings and ensure that future policy considerations are based upon consideration of the data outlined in this report. The Victorian agencies should also consider the degree to which they would seek the data collected by the Bushfire CRC to be linked to that of other bodies in future phases of this work.

It is further envisaged that the recently announced \$15M extension to the Bushfire CRC's funding to examine issues arising from the Victorian Fires, will be partially used to undertake further analysis. There are many opportunities for further detailed analysis over and above the work to be undertaken from July 2010 under the Bushfire CRC extension.