BUSHFIRES:

A Geography resource for Australian students

GEOGRAPHY TEACHERS' ASSOCIATION OF VICTORIA INC.

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Contents

Introduction

Fire has been a part of the Australian environment for a long time, with early explorers noting the bushfires burning across the landscape. Fire has shaped the vegetation types in Australia and has had an impact on human societies, beginning with Indigenous Australians and continuing through European settlement. The majority of Australians live in coastal and urban areas and have little experience of bushfire. This includes those living on the rural-urban fringe—a place where bushfire can have deadly consequences. An effective fire management strategy, supported by ancillary services and trained volunteers, can succeed in minimising the loss of life and property in a bushfire crisis. In Australia, a strategy has been developed where people are informed about the ways to prepare for bushfire, how to take precautionary action and how to respond in a manner that reduces the impact of a bushfire event.

This resource has been written and developed for Geography teachers and students at the lower secondary level. It provides an understanding of bushfire, increasing the awareness about the threat of these events to people and places. As people live and seek recreation in areas prone to bushfire, it is important that students become aware of the actions that can be taken to prepare for a bushfire, and reduce the damage and impact of such an event.

Curriculum Links

This resource uses the Victorian Essential Learning Standards (VELS) curriculum in the Humanities (Geography) Domain as a basis of development. The Humanities in Prep to Year 10 involve the study of human societies and environments, people and their cultures in the past and the present.

Geography is the study of physical and human environments from a spatial perspective. It provides students with the knowledge and skills to observe and describe places on the surface of the Earth and to analyse and provide explanations from a spatial perspective of human and physical phenomena and their complex interactions.

VELS Geography

Level 5 Knowledge and skills

Students:

- use a variety of geographic tools and skills, together with an inquiry-based approach, to investigate the characteristics of the regions of Australia
- explore how and why, over time, human and physical interactions produce changes to the characteristics of regions
- extend their knowledge and understanding of physical phenomena, including natural hazards, and of the physical processes that produce them
- identify patterns of distribution and occurrence of major physical features and their interrelationship with human activities
- apply their knowledge and understanding of scale, grid references, legend and direction to use large-scale maps (such as topographic maps), as sources of spatial information, as well as other spatial representations
- research and analyse photographs, maps, satellite images and text from electronic media and add these to their presentations
- learn to draw overlay theme maps
- recognise that parts of the Earth’s surface can be represented in various ways, at different scales, and from different perspectives on a range of maps, photographs and satellite images.

Level 6 Knowledge and skills

Students:

- develop knowledge about the operation of one of the major natural systems that are part of the biosphere and atmosphere. For example, the hydrologic cycle, plate tectonics or the weather
- investigate the interaction of human activities with the natural environment
- develop skills to evaluate the factors contributing to the development of these issues, identify strategies to address them and explore ways of managing them
- accurately interpret information on different types of maps and photographs at a range of scales, and use map evidence to support explanations, draw inferences and predict associated outcomes.

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What is a bushfire?

Fire is a natural part of our environment. It has shaped the landscape through natural ignition (lightning) and indigenous burning practices for thousands of years. Fire has shaped Australia's natural vegetation and has had an impact on human societies, beginning with Indigenous Australians and continuing through European settlement to the present. Victoria is one of the most bushfire-prone areas in the world. Having knowledge of fire, its causes, behavior and impact on the natural and human environment, will help individuals and communities to be prepared in the event of a bushfires. This knowledge will help people to plan and adopt ways of living with fire in the Australian environment.

Wildfire is a term adopted internationally to describe a fire which is burning out of control in the open. The term **bushfire** has a long history in Australia and is commonly used by people to describe any fire—grass, scrub or forest—burning out of control.

Figure 1.1: *A bushfire can have major impacts on natural and human environments*

What is fire?

Combustion

Fire is a high temperature, chemical reaction which releases energy as heat and light. Another word often used to describe this process is **combustion.** For combustion to occur, fuel, heat and oxygen must be present and interact. This is often referred to as the 'fire triangle' and can be seen in figure 1.2. If one of these components is removed the combustion process cannot continue.

Figure 1.2: *The fire triangle*

The materials that burn in a fire are called fuel. Most materials will burn, although materials high in carbon and hydrogen, such as paper and wood, combust more easily. A solid fuel will become drier as heat causes moisture to evaporate. Heat is required to start the chemical reaction of combustion. If there is enough heat, the fuel will begin to break down and give off a cloud of gas. It is this gas cloud which burns in the chemical reaction of combustion. For a fire to produce flames it requires oxygen. Without sufficient oxygen the chemical reaction producing the flame will cease—however, glowing combustion or smouldering may continue.

In bushfires, solid fuel such as leaves, twigs, bark and trees—shown in figure 1.3—break down under the influence of heat and produce combustible gases which then burn. The hot, combustible gases rise by convection, drawing in surrounding air and mixing it with the fuel gases.

Figure 1.3: *Fuel for a bushfire can be twigs, leaves and bark*

Heat transfer

Heat can be transferred in three different ways: by **radiation, convection** and **conduction.**

Radiation is a form of heat energy that travels in straight lines in all directions from its source. It is the direct heat you feel from a fire and comes from the flames and any smouldering fuel or heated surfaces (figure 1.4). Burning fuel and flames radiate large amounts of heat, which act on fuel immediately around the fire, preheating and drying it out. This may bring it to a temperature where it ignites. The intensity of radiant heat will drop with increasing distance from its source.

Figure 1.4: *Radiation of heat in all directions*

Convection is the transfer of heat through air, causing that air to rise. As a fire gains in intensity, the air above is heated to an even greater temperature, so the air rises faster. Cooler air must move in towards the fire at ground level to replace this heated air. This is known as **indraught wind.** It is this process that forms the convection column or rising hot air and the smoke plume above the fire. The convection current can carry ash, embers and small pieces of burning fuel. Convection has important implications for firefighters as a large fire may create strong indraught winds which can alter the behavior of the fire. The burning embers can also be carried away from the fire and start other fires. This is called **spotting.**

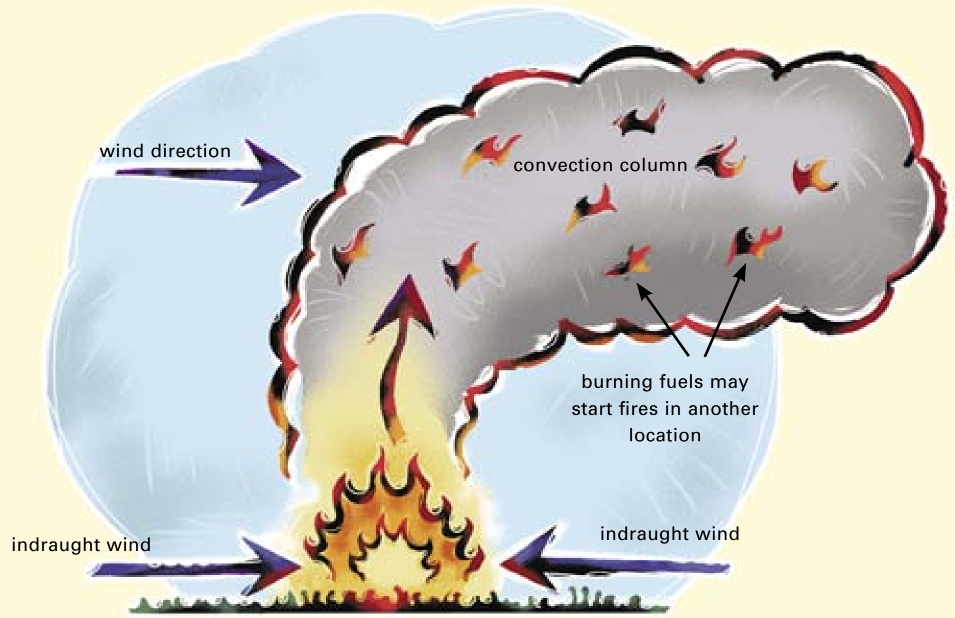

Figure 1.5: *Convection*

Conduction is the transfer of heat through a solid object from a region of higher temperature to a region of lower temperature. Different substances conduct heat at different rates. For example, metals are more effective conductors of heat than wood. In bushfires, conduction refers to the movement of heat through the fuel itself.

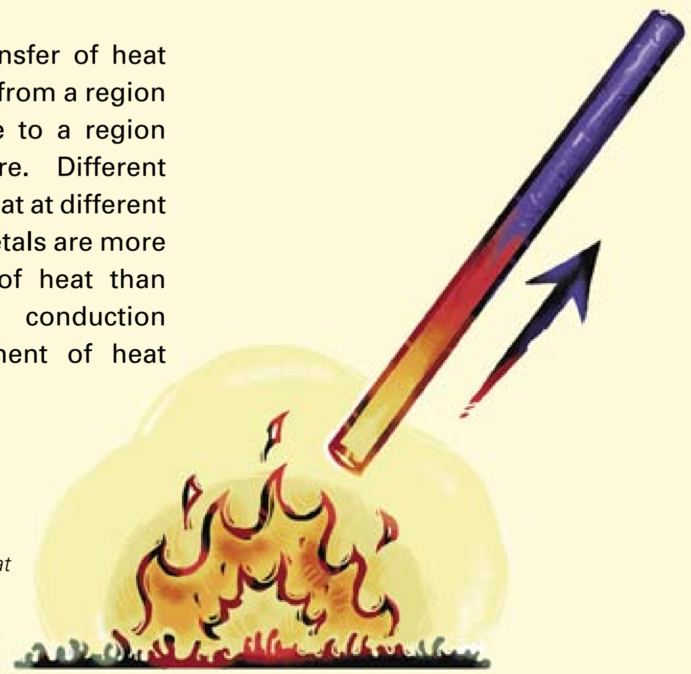

Figure 1.6: *Conduction of heat through a solid object*

How do bushfires burn?

The three stages in the process of combustion—pre-heating, ignition and flaming combustion—are shown in figure 1.7.

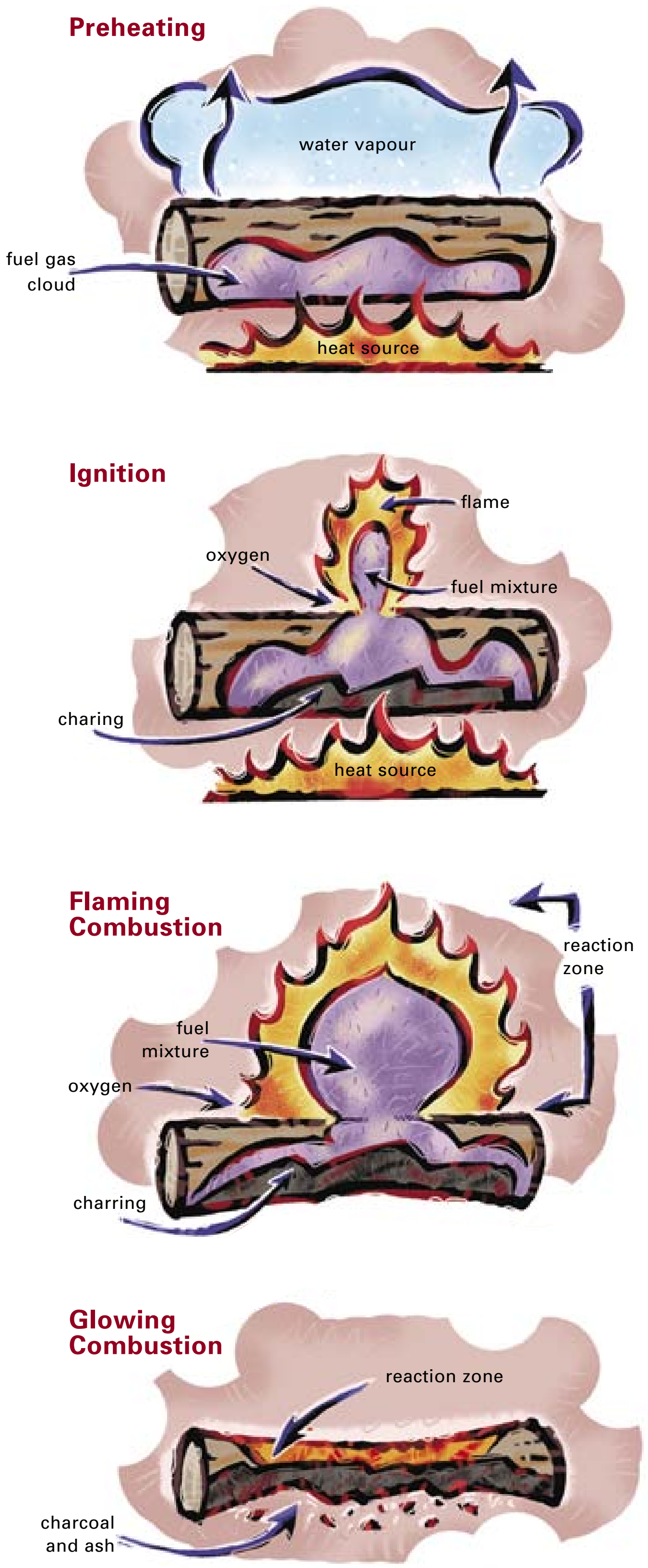

Figure 1.7: *stages of combustion*

These stages operate together during the start of a bushfire.

Pre-heating

Before fuel will burn easily, moisture must be removed. Hot, dry weather or the heat of an approaching fire will evaporate moisture. The fine fuels such as small twigs, dry leaves and grass lose that moisture more easily and provide the initial fuel for the fire to burn. Plant matter contains cellulose, a carbon based material. Heat from a match, electrical spark or other source causes the cellulose particles to break down into smaller combustible products which are given off as a cloud of fuel gas.

Ignition

The temperature of the cloud of fuel gas is raised by the heat source until ignition occurs. The fuel gas reacts with oxygen from the air and becomes flame. Heat energy is released.

Flaming combustion

The heat produced by the flames pre-heats the nearby fuel which also gives off fuel gas. The fire spreads as this gas ignites. The more fuel available, the more gas is produced. As the heat energy increases, fuel gas is given off from larger fuels such as branches, logs and tree trunks. As the amount of fuel gas given off is reduced, the flames die down until there is not enough fuel gas to support further flaming combustion. Glowing combustion takes over, eventually leaving blackened charcoal and white ash, as shown in figure 1.8.

Figure 1.8: *Glowing combustion and charcoal left after flames have died down*

Fire intensity

Fire intensity refers to the heat generated by a fire. It is related to the type, amount and density of the fuel available and the speed at which the fire moves. Fire intensity also indicates how difficult a fire will be to control and how much damage might occur. For example:

- a fuel reduction burn is a low-intensity fire, usually around 500 kW/m. This type of fire is deliberately lit by authorities to help reduce the amount of undergrowth in a forest
- a fire with an intensity of 4000 kW/m in a forest or up to 10 000 kW/m in grassland would probably be controlled by a well-equipped firefighting team
- a bushfire on a hot, windy day is typical of a high intensity fire. Forest fires can reach an intensity of over 100 000 kW/m. This energy is capable of melting glass and metal and twisting steel beams.

> A single-bar radiator, used for heating in homes, has a heat energy of one kilowatt (1 kW). A fire producing 400 kW per metre is equivalent to the heat of four hundred bar radiators per metre.

Figure 1.9: *The heat from a high intensity bushfire has destroyed this machinery*

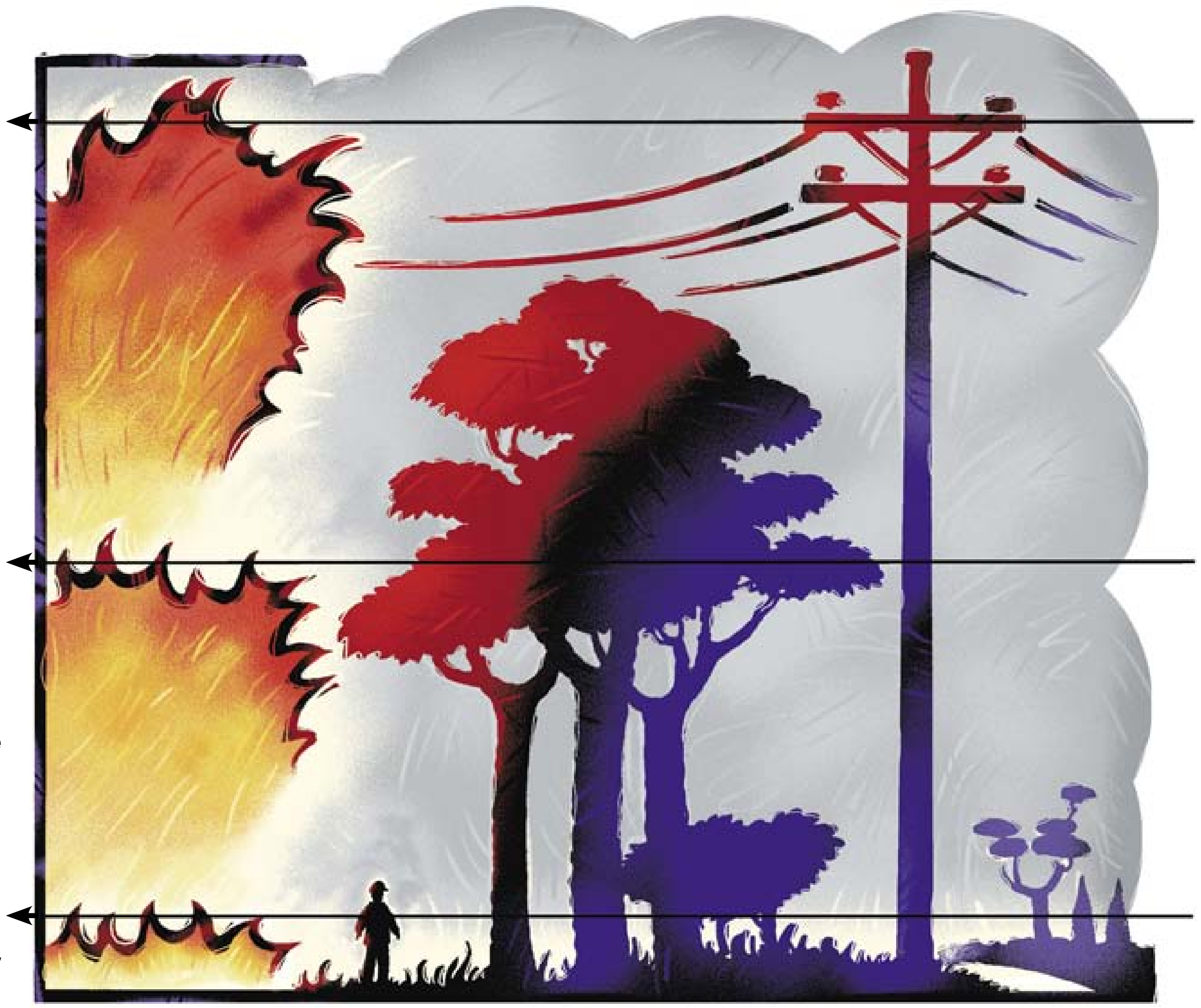

Figure 1.10: *Flame height and fire intensity*

Observing the height of bushfire flames can also give an indication of fire intensity. As shown in figure 1.10, low intensity fires have flames of less than 1.5 metres while very high intensity fires will have an average height greater than 14 metres. Note that prevailing winds can influence flames causing them to 'bend over' and look shorter.

Extinguishing fires

There are three basic methods of extinguishing a fire, each designed to break the fire triangle. These include:

- cutting the oxygen supply to smother the fire
- reducing the temperature to cool the fire
- removing the fuel to starve the fire.

In many instances, a combination of these methods is used to extinguish a fire.

Cutting oxygen supply

This is an efficient form of attack when dealing with small fires, but is usually too difficult for large fires. Methods used include: shovelling soil over a fire or applying chemical foam. In a bushfire shovelling soil may put out the flames but embers may continue to burn slowly and even reignite. Foam has the added benefit of cooling the fire as water drains from it.

Reducing temperature

Heat causes fuel to give off vapours which then burn. By removing heat, the combustion process is interrupted. Water is used to cool the fuel to the point where combustion stops. Water is effective because it absorbs and removes heat energy as it turns to steam. It also cools the fuel below its ignition temperature. This is very effective for small fires but the water must be directed onto the burning fuel, at the base of the flames. Applying water to the flames alone will not stop the burning process as the fuel will simply continue to give off flammable vapours. In some instances it may be necessary to drop water onto a fire from a plane or helicopter.

Figure 1.11: *Helicopter preparing to drop water on a bushfire*

Figure 1.12: Bulldozers clearing a fire break

Removing fuel

Dry firefighting is the term used to describe the control of fire without the use of water. There are a range of methods that can be used, such as using a rake or hoe or bulldozers to clear a control line or large area, or deliberately back-burning along the inner edge of a control line to consume the fuel in the path of a bushfire, as shown in figure 1.12.

Types of bushfires

A bushfire is an unplanned vegetation fire in grass, scrub and forest areas. The three main types of bushfire are:

- ground fire
- surface fire
- crown fire.

Fires are often described in terms of the environment in which they burn.

Grassfires occur mainly on grazing, farming or remote scrub country. They can destroy fences, livestock and buildings and result in loss of human life. Grassfires can travel at speeds of up to 10 km/h but speeds above 30 km/h have been recorded.

Forest fires Forest fires occur in woodlands and forests, often in isolated mountain environments. Under certain weather conditions, fires in Australian eucalypt forests cannot be stopped and often destroy homes and settlements which border such areas. Rapid heating of forest fuels can create tall flames which can flare up to three times the height of the forest. Clouds of dense smoke can hide the fire front from both ground and aerial observation. Severe forest fires can produce large amounts of embers and spread at speeds of up to 16 km/h.

Figure 1.13: *Characteristics of crown, surface and ground fires*

Figure 1.14: *A grassfire*

Parts of a bushfire

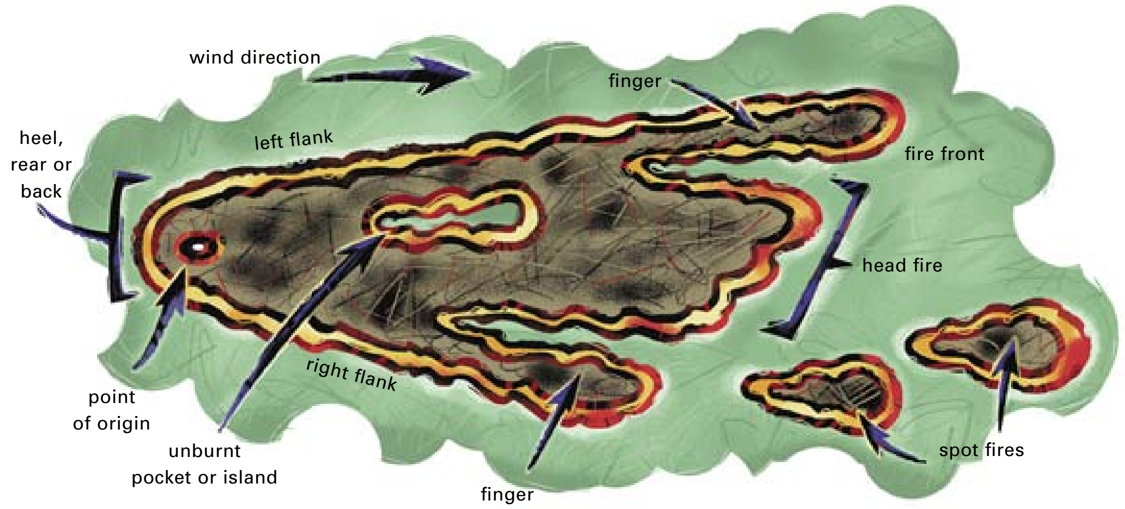

Figure 1.15: *The parts of a bushfire explained*

Figure 1.16: *The back of the bushfire can be seen in this aerial photograph.*

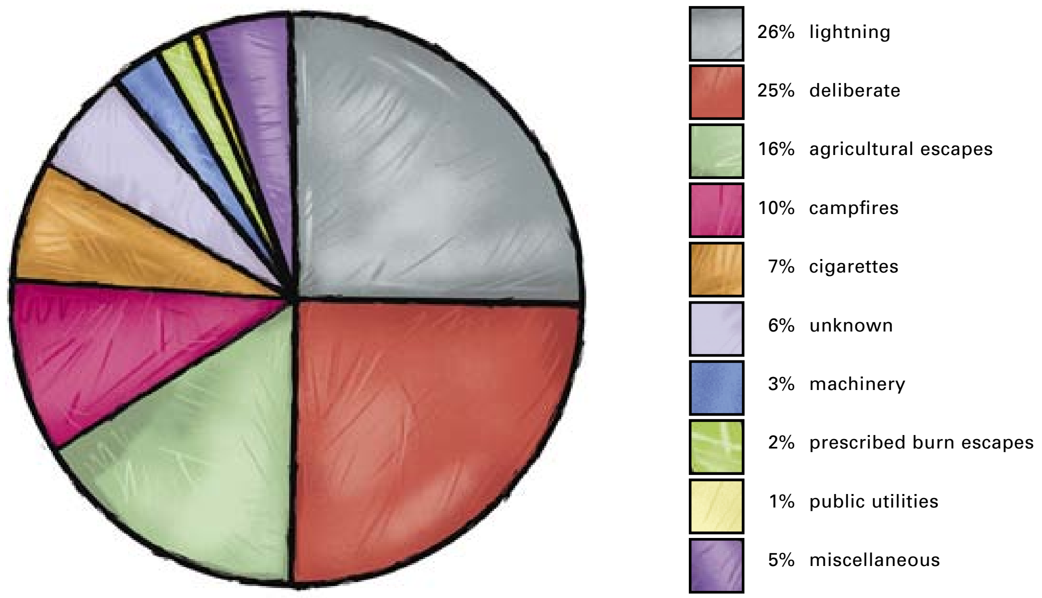

Figure 1.17: *Causes of bushfires in Victoria: 20 year average*

How do bushfires start?

Bushfires can be caused either naturally or by the actions of people, either accidentally or deliberately. Although lightning is a common cause of bushfires, most are started by people. During extreme bushfire weather any fire has the potential to be devastating. The causes of bushfires are shown in figure 1.17.

Natural causes

Lightning strikes are the cause of almost all bushfires of natural origin. There are, on average, more fires started by lightning than any other cause. On 7 January 2003, lightning associated with thunderstorms across eastern Victoria and southern NSW was responsible for starting over 80 fires in Victoria and more than 40 fires in NSW and the ACT. The resulting Alpine Fires in Victoria burnt over one million hectares.

Human causes

All other bushfires on public land are started as a result of human activity. Some examples of fires caused by people include the following:

- **Campfires:** most of these fires start when people leave campfires unattended or not properly extinguished. On average, around 1500 hectares of public land are burnt each year as a result of careless camping practices.
- **Burning off or agricultural burns:** farmers may burn vegetation on their properties for a number of reasons including weed control, burning of crop debris and rubbish removal. Unattended burns are most likely to 'escape' and become bushfires. These fires cause over 15 per cent of bushfires each year.
- **Equipment or machinery:** any equipment or machinery that generates heat or sparks is a potential cause of bushfires. Examples include: chainsaws, slashers, welders and exhausts from vehicles. Power lines, rubbing against tree branches in high winds, can also cause bushfires. On 7 February 2009, five major bushfires were believed to have been started from failed electrical assets such as conductors clashing or contacting trees.
- **Deliberate:** this category includes all fires which are deliberately lit and develop into bushfires. Examples include children playing with fire, farmers deliberately lighting fires without necessary permits or fires lit with intent to damage or destroy property.

Figure 1.18: *Bushfires can be caused by lightning*

Figure 1.19: *A damaged power pole with transformer*

Bushfires started by unusual events include:

- smouldering poultry feathers, blowing into the bush, burn 100 houses
- a bulldozer blade striking a rock
- a man suffering a heart attack while smoking, drops his cigarette
- an electrocuted bird smouldering on dry grass.

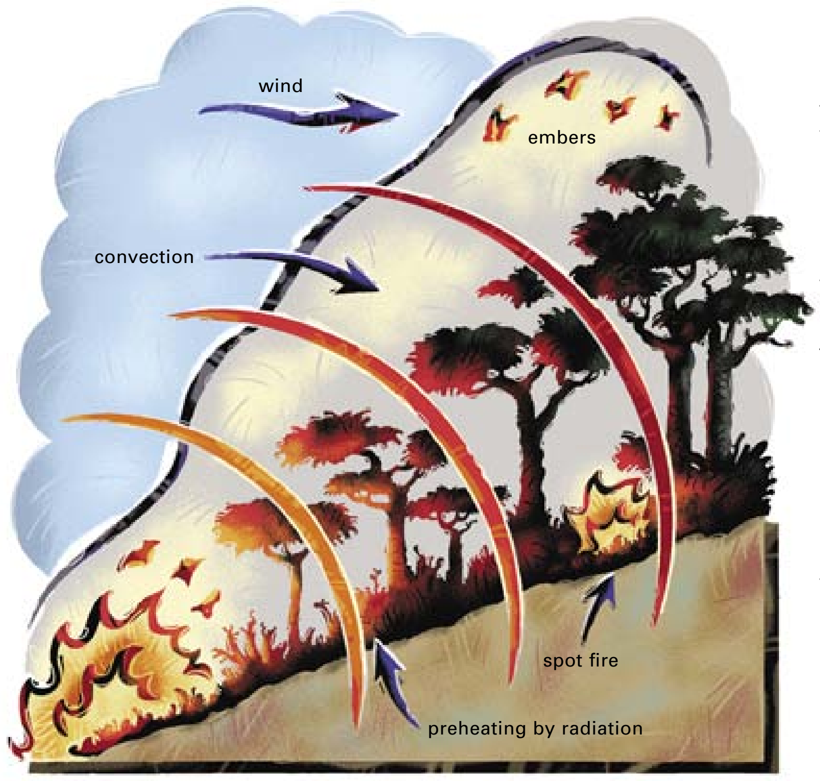

Figure 1.20: Spread of fire by radiant heat, convection and spotting

Figure 1.21: Patterns of fire spread

How do bushfires spread?

A fire spreads when it has enough heat to keep it burning into unburnt areas. A spreading fire is really a transfer of energy. In a bushfire, there are three main ways in which this happens, as shown in figure 1.20.

The vegetation ahead of the fire is heated by the approaching flames. The radiant heat from the fire does not penetrate deeply but affects the surfaces exposed to heat. The hotter the fire, the greater the amount of radiant heat and the faster the fire will spread as it dries out the fuel in its path. Heat radiation decreases rapidly with increasing distance from the fire.

Convection is the movement of heated air. Smoke and ash is carried upwards by convection currents. As the fire grows, an increasing volume of air is heated and rises. Strong winds also develop which can alter fire behavior. The rising hot air lifts **firebrands** or **embers** which may be blown beyond the fire front igniting spot fires.

Figure 1.21 shows several patterns of fire spread. In areas where there is uniform vegetation and no wind, the spread of the fire occurs in a slowly widening circle and can easily be extinguished. This pattern is common. Factors such as fuel loads, wind speed and direction, and slope alter the rate of spread and the intensity of the fire. Many bushfires are irregular and elongated in shape.

Activities

1. Make a copy of the fire triangle from figure 1.2. Annotate your diagram with words to describe the sources of each of the elements which make up this triangle.

2. Explain the role of radiant heat on the fuel supply of a bushfire.

3. Sketch a diagram and use labels to show how convection can form spot fires ahead of a bushfire.

4. How does a prolonged period of dry weather or drought affect the fuel for a bushfire?

5. Construct a table similar to the following one to show the advantages and disadvantages of each of the three main types of fire fighting in controlling a large bushfire.

Method of fire fighting	Advantages	Disadvantages
Cutting oxygen supply		
Reducing temperatures		
Removing fuel		

6. a. Make a copy of the cross section of a forest shown in figure 1.22. On your diagram draw in, shade and label:

   i. ground fire ii. surface fire iii. crown fire.

   b. Suggest a reason why surface fires are the most common type of bushfire.

   c. Give three dangers associated with crown fires.

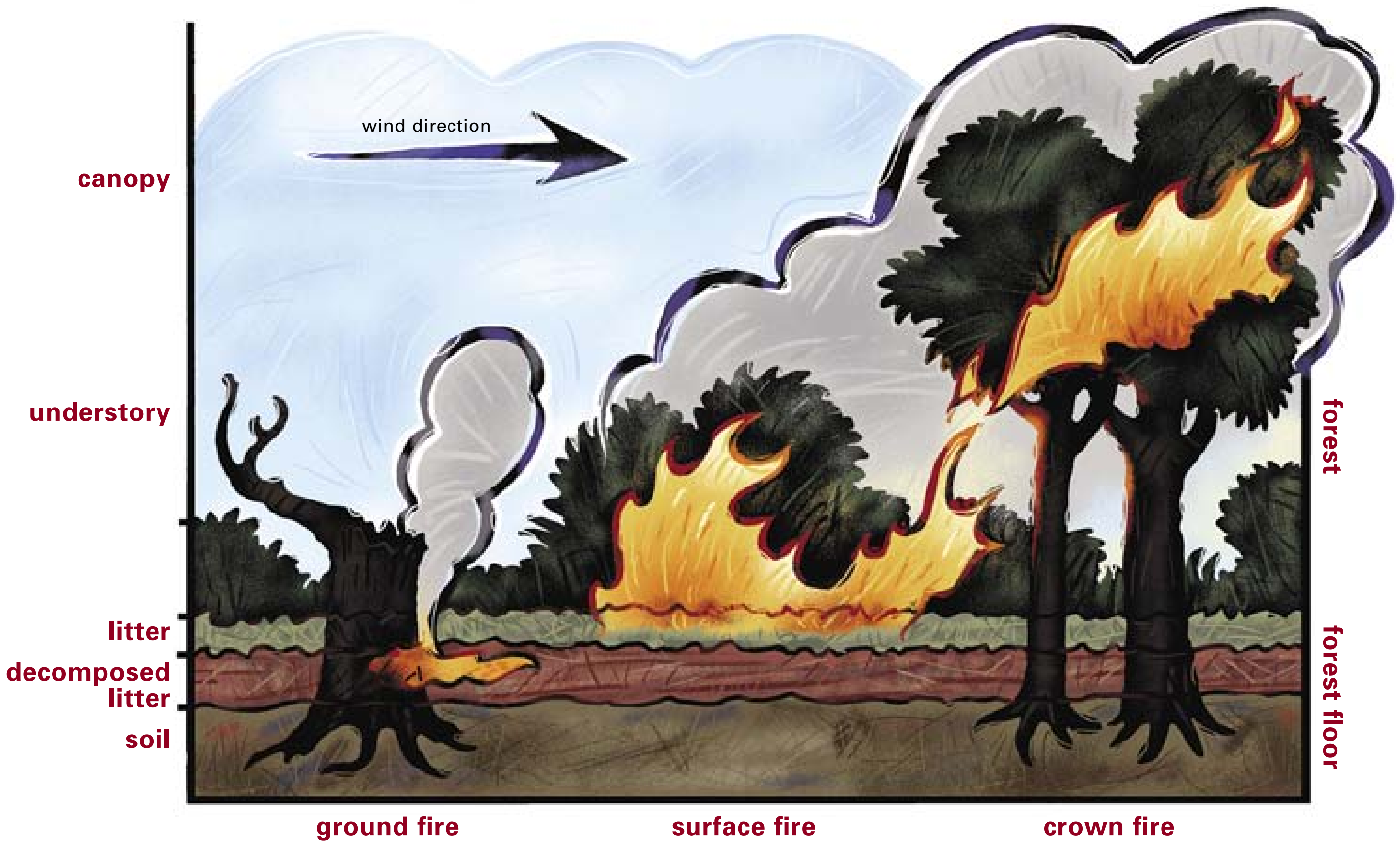

Figure 1.22: *Types of fire in a cross sectional view of an Australian forest*

7. a. Use tracing paper, make a copy of the map showing the extent of the fire shown in figure 1.23: The Cudgee and Ballangeich Fire perimeter. On your map identify and label the following parts of a bushfire:

- right flank
- left flank
- fire front
- finger
- point of origin
- spot fires
- unburnt pockets
- wind direction.

Complete your map by providing a suitable title, scale and orientation arrow.

b. Using the scale provided, measure the distance from:

i. the origin to the head of the fire

ii. the western to the eastern flank at its widest point

iii. the fire front to the furthermost spot fire.

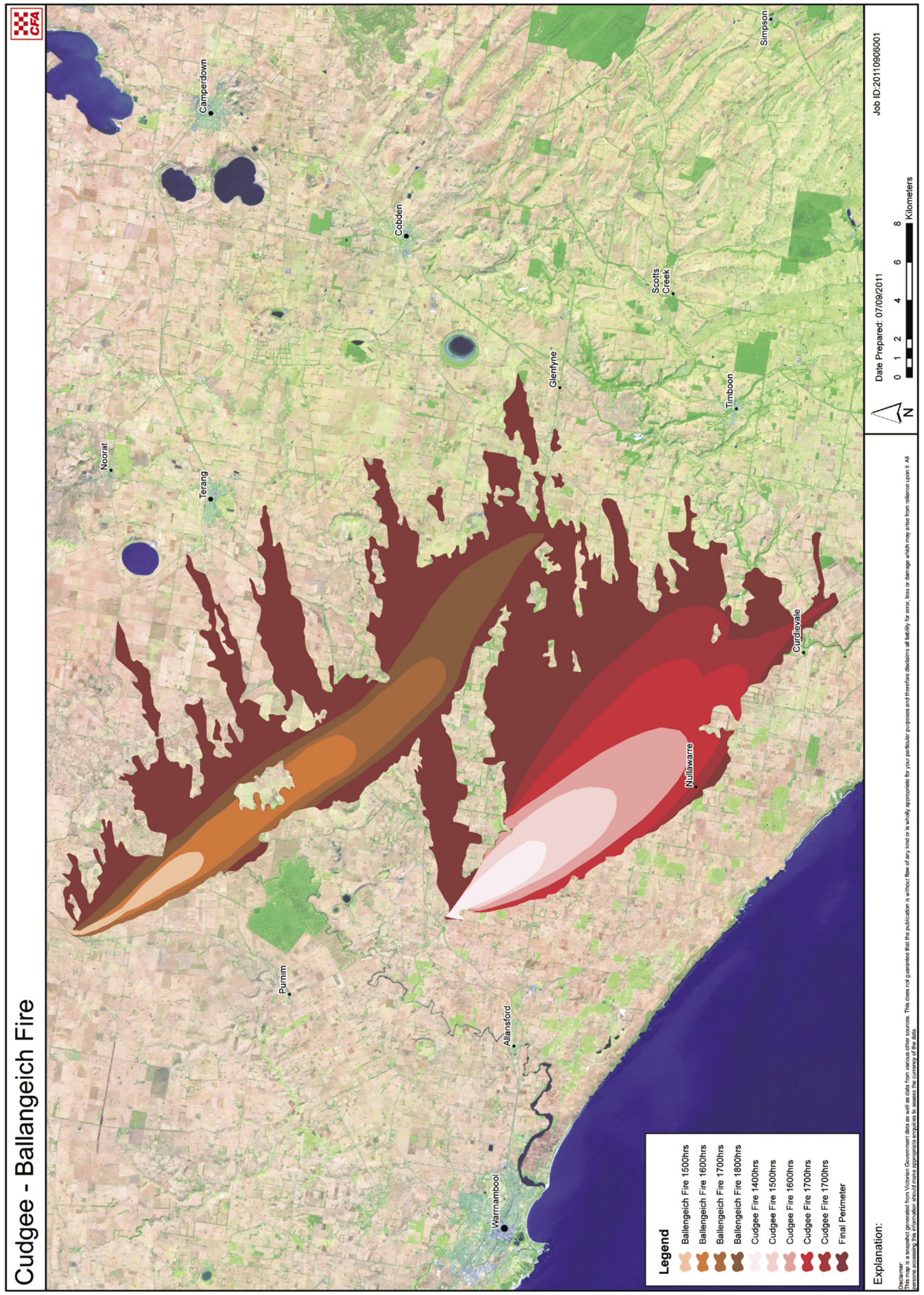

Fig. 1.23: *The Cudgee and Ballangeich Fire perimeter*

8. Study the data in figure 1.24.

a. Draw a bar graph to show the number of fires of different sizes from January 1998 to January 2011.

b. Which size fire was the most common over this time period? How would you explain this?

c. Which size fire occurred the least? Why would there be fewer fires of this size?

d. What does this data suggest about the early containment of fires?

	Large	Medium	Small	Spot
Jan 98	8	36	146	475
Jan 99	12	42	172	520
Jan 00	3	20	115	420
Jan 01	22	69	244	891
Jan 02	9	37	119	485
Jan 03	14	47	159	714
Jan 04	7	36	135	541
Jan 05	7	33	152	550
Jan 06	21	54	90	685
Jan 07	6	18	66	679
Jan 08	1	10	41	693
Jan 09	5	15	55	924
Jan 10	9	14	58	529
Jan 11	1	9	18	221
Sizes of fires:	Large >50 ha	Medium 5–50 ha	Small 0.5–5 ha	Spot <0.5 ha

Figure 1.24: *Number of fires of different types and size 1998–2011*

9. Study the data in figure 1.17.

a. How many bushfires on public land in Victoria are caused each year by cigarettes and matches?

b. What are the two major causes of bushfires on public land in Victoria each year?

c. What is meant by public land?

d. Which fire event causes 2400 hectares of land to be burnt on average each year?

10. Read the section 'How do bushfires spread' and then create an annotated sketch, or series of sketches, to show how bushfires spread by radiant heat and convection.

11. Outline an advertisement campaign you would design to warn people of one of the causes of bushfires.

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CFA & GTAV *Bushfires Living with Australia's Natural Heritage,* June 1995

Mraz, J. *Bushfires A Threat to People and Place*s, GTAV, 2002

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Where and when do bushfires occur?

Introduction

Bushfires are not confined to Australia. There are large regions of every continent, with the exception of Antarctica, that experience regular bushfires. As can be seen in figure 2.1, there can be thousands of fires burning in the world on any one day of the year. A breakdown of the causes of these is summarised in figure 2.2.

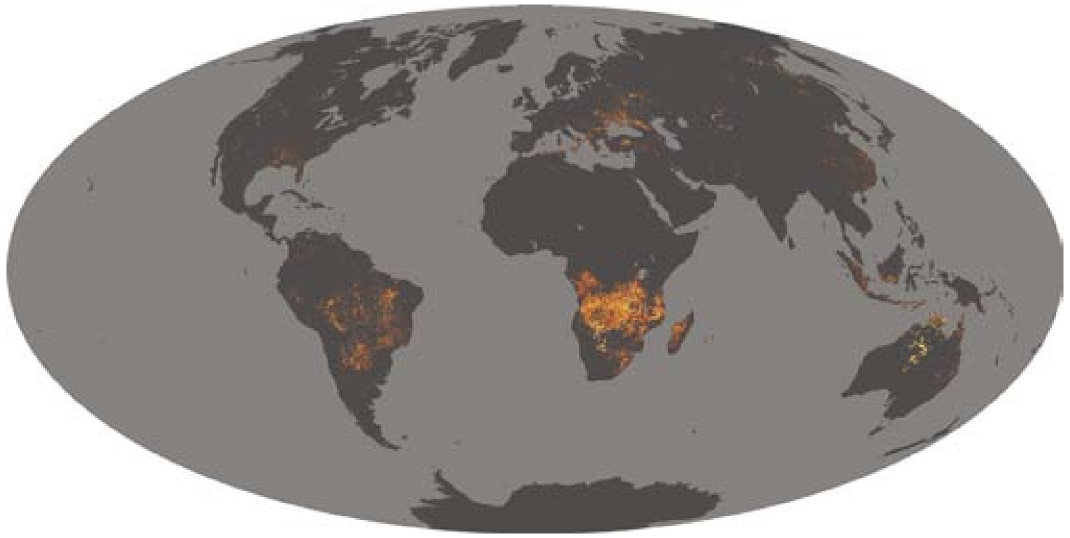

Figure 2.1: *Satellite image showing the distribution of fires in July 2011*

Continent	Causes of wildfires	Description
North America	Lightning in USA and Canada.	Over 50 per cent of Canada and 33 per cent of USA is covered by forest. Fire season lasts from early Spring to mid Autumn.
Central America	97 per cent of fires in Mexico and Central America are lit for agricultural needs.	Fires can begin in December and burn through to July.
South America	50–90 per cent of uncontrolled wildfires begin as agricultural burns and then grow out of control.	Fire is used to clear large areas of almost impenetrable forest for cultivating crops, grazing livestock or creating roads. The burns are usually timed for the drier period, from May to October.
Europe	On average 50 000 fires burn annually in the countries surrounding the Mediterranean Sea, usually resulting from accidents or human negligence.	In the cooler northern European countries extensive regions of forest can burn during the summer months. Most fires occur during spring and summer months.
Africa	Approximately 90 per cent of fires are a result of human activity, with burning planned to clear dead vegetation after cropping and weed removal. Africa is very prone to lightning storms, which is the second biggest cause of wildfire.	Extensive regions of grasslands in southern, western and eastern regions are very prone to fire in the dry seasons of May–October (southern Africa) and January–April (northern Africa).
Asia	Wildfires in Asia are largely lit to clear waste from harvested crops, especially rice, and to clear forests for planting. Lightning accounts for 30 per cent of fires in northern China's forests.	Wildfires are more prevalent in Southeast Asia during times of El Nino when prolonged dry seasons occur.
Oceania	Most fires in Australia begin naturally, though there is some controlled burning close to major population centres. New Zealand has relatively few fires, less than 3000 per year mostly to improve pasture and encourage new growth. In Fiji most burning is a result of clearing after harvesting sugar cane.	Fires begin in the north of Australia during the dry season. South-eastern and south-western Australia experience the worst fires in summer and autumn.

Figure 2.2: *Main causes of fires in each continent*

Figure 2.3: *'Aborigines using fire to hunt kangaroos', Joseph Lycett, c1820. National Library of Australia.*

How has fire been used in the Australian environment?

Fire has always been a feature of Indigenous Australian life. For thousands of years, the Indigenous Australians of Victoria used fire as a tool to signal; to prepare food; to promote vegetation types that made hunting and gathering food easier; and to regenerate vegetation. Fire was also used during ceremonies.

Indigenous Australians understood that maintaining the environment with fire was critical to their own survival. They used fire to manage the land.

Traditional knowledge of burning told the people when and where to burn using cues taken from the environment including weather, vegetation type, growth stages of the vegetation, and the presence or absence of particular plant and animal species.

The early settlers used fire to clear the bush for agriculture, mining, urban settlement, roads and railways. Large trees were ring-barked or cut down and left to dry out. During the hottest, driest weather fires were started to destroy as much native vegetation as possible. Sometimes this burning escaped and caused major bushfires.

As Europeans settled the land, Indigenous Australians became unable to care for their country with traditional fire practices. The change in fire practices, along with farming and settlement patterns have changed the type and structure of vegetation in much of Australia. Expert opinion varies on the nature and extent of the vegetation change, because evidence of pre European vegetation cover and indigenous fire practice is poor for most of Australia. However, all agree that the influence Indigenous Australians had on vegetation through the use of fire was profound.

In the 20th century, bushfire legislation was introduced to reduce the number of fire starts, and improved fire suppression capability was directed to prevent small fires becoming big. Fire managers believe that the modern Australian landscape— no longer burnt by Indigenous Australians— has increased levels of fuel available and that this has made severe fires more likely. It has been proposed that the wider use of frequent small fires (as was the indigenous practice) to reduce fuel levels will significantly reduce bushfire risk by reducing the severity of big fires.

Figure 2.4: *Early settlers fighting a fire in the mid nineteenth century*

A Koori myth from Victoria tells how Crow stole fire from the seven women guardians. In the Dreamtime only these seven women knew the secret of fire and refused to divulge how it was made. Crow decided that he would get their secret. He made friends with the women and found out that they carried fire at the ends of their digging sticks. He also found out that the women were fond of termites, but afraid of snakes. He buried a number of snakes in a termite mound, then told the women he had found a large nest of termites. They followed him to the spot and broke open the mound. The snakes attacked them and they defended themselves with their digging sticks. This caused fire to fall from the sticks. Quickly, Crow picked up the fire between two pieces of bark and ran away. Now Crow in his turn refused to share fire with anyone. Every time someone asked him, he mockingly called out, 'Waa, waa.' He caused so much strife that even he at last lost his temper and threw coals at some of the men who were pestering him for fire. The coals caused a bushfire in which he supposedly was burnt to death, but the eternal trickster came to life and the survivors heard his mocking 'Waa, waa' echoing from a large tree.

Figure 2.5: *Koori myth from Victoria*

Where and how often do bushfires occur in Australia?

In Australia, the frequency of bushfires differs from region to region. Bushfire cycles—the average period of time between bushfires—depend on the climate and the distribution and life cycle of vegetation. The amount of growth, drying out and dying vegetation, affect the potential for fire and its intensity. Figure 2.6 shows the occurrence of large bushfires and the bushfire seasons while figure 2.7 shows the population distribution in Australia. It is interesting to compare the two maps.

Why does Australia experience bushfire?

The distribution of bushfire areas depends on the vegetation and climatic conditions of the region.

Vegetation

For long periods, the vast desert regions of Australia, which cover more than 50 per cent of the continent, have little or no vegetation available to burn. The central and mid north-west of Australia are grassland regions where farming of crops and cattle occurs. These areas of grassland, open scrub and woodland experience bushfire from time to time. The remaining four per cent of the continent's vegetation is forest and can easily burn when dry.

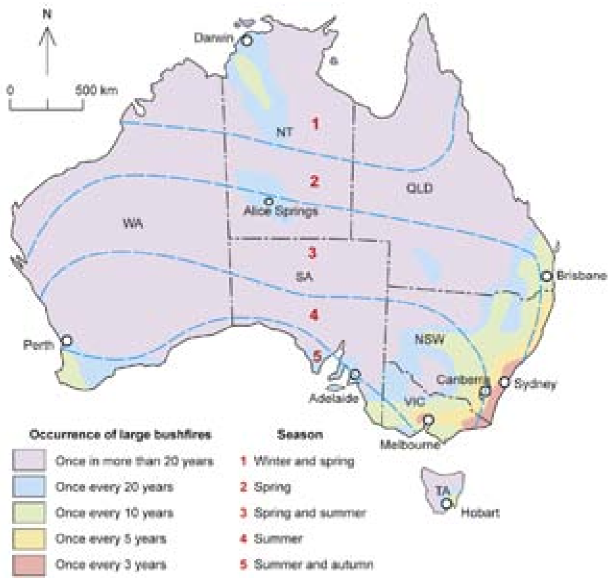

Figure 2.6: *Occurrence of large bushfires and the main fire seasons for Australia*

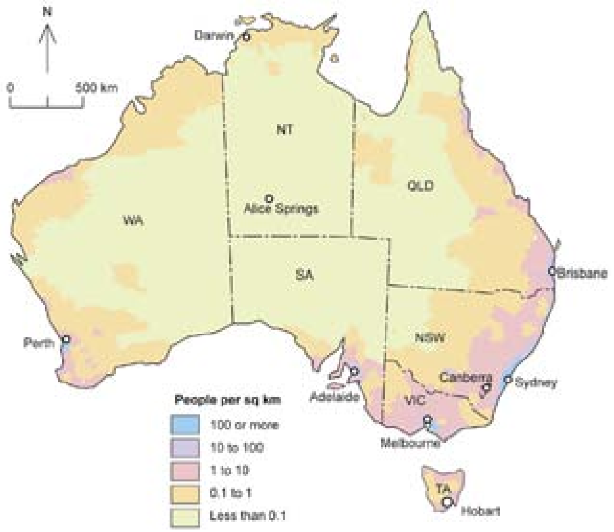

Figure 2.7: *Australia's population distribution*

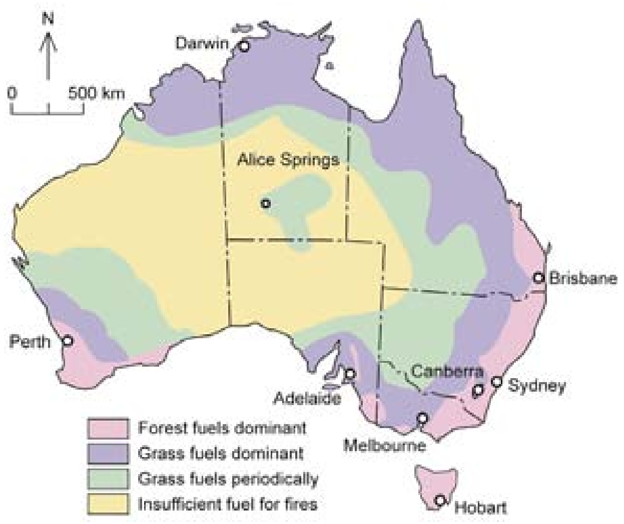

Figure 2.8: *Distribution of fuel types in Australia*

Figure 2.9: *Desert vegetation is sparse*

Figure 2.10: *Extensive regions of grasslands cover much of Australia*

Much of Australia is covered by grassland and grassy woodland. Pasture species have an annual cycle in which the plant dies or becomes dormant and loses moisture. This drying process is called curing. By midsummer the plants are said to be completely cured and are reactive to the relative humidity in the atmosphere. When there is low relative humidity, grasslands can be tinder dry and become a high fire risk.

During the summer months, the eucalyptus forests of south-eastern Australia are vulnerable to bushfire. The forest floor is covered with a thick layer of densely-packed litter and medium to dense undergrowth, while the canopy of leaves interlock. In these dry forests, the amount of litter means that fire is an ever-present danger during summer. In mountainous areas, where it is wetter, fire does not occur as often and litter builds up over a long time. On a hot, windy day, after a period of drought, these areas can be vulnerable to intense bushfires.

Figure 2.11: *Eucalypt forest*

Climate and weather

In Australia, areas which experience a **temperate climate** tend to have the most bushfires. The conditions associated with a temperate climate—moderate winter rainfall and warm to hot conditions in summer—occur throughout the south-eastern and south-western regions of Australia. The mild winter temperatures and plentiful rainfall encourages vegetation growth. This is cured by the high summer temperatures and the amount of fine fuel necessary for a severe bushfire becomes available. Severe bushfires often occur in south-eastern Australia when the weather conditions are similar to those shown in figure 2.12.

Strong northerly winds associated with high pressure systems blow across the desert region of central Australia in summer, bringing hot, dry air to south-eastern Australia. These winds reduce the moisture content of the grasslands and forests and create the conditions for fires to burn.

At the same time, a cold front approaching south-eastern Australia from the west brings a mass of cool, moist air. The heavier, cooler air is able to force its way under the hot dry air ahead of it. The cold front causes rapid changes in wind direction, temperature and humidity. The cool air is often associated with strong, gusty, south-westerly winds which can change the direction of the fire, turning its eastern side into a new front. These strong, gusty winds also create rapid fire spread.

Fire in the Victorian landscape

Victoria is one of the most bushfire prone regions in the world. Natural ignition (lightning) and Indigenous Australian burning practices have shaped our ecosystems over tens of thousands of years. Many ecosystems are reliant on bushfire to regenerate and maintain health. Around 600 wildfires occur in Victoria's parks and forests in an average summer. In the last 150 years, wildfires have resulted in considerable loss of life and much property damage.

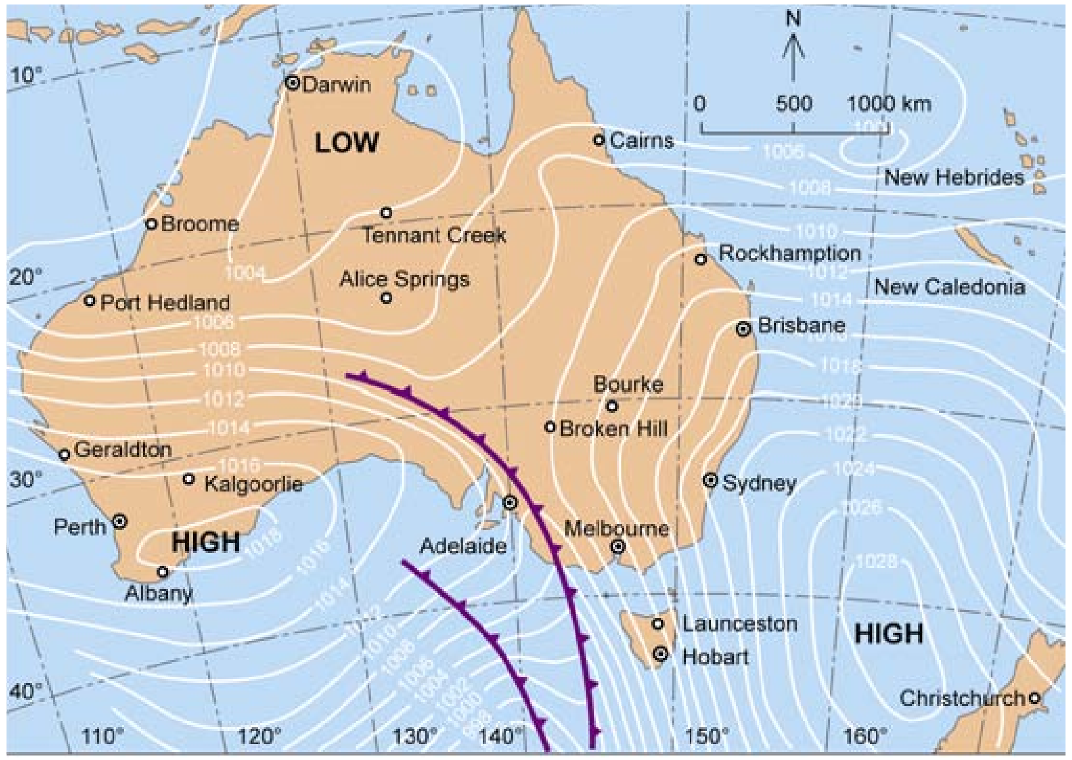

Figure 2.12: *Typical summer weather patterns over south-eastern Australia*

Over time, successful firefighting and fire suppression have removed much of the natural fire cycle from the Victorian landscape and have increased the length of time between fire episodes across large tracts of forested areas.

Increased bushfire threat

Between 1997 and 2007 there was a significant increase in the number and intensity of bushfires and in the area burnt by them. Of the 52 significant bushfires recorded in Victoria between 1851 and 2010, two-thirds have occurred in the past 60 years. There is a direct link between drought and increased fire activity and intensity. Over the last century, major fire events, including: Black Friday 1939, Ash Wednesday 1983, the Alpine Fires 2003, the Great Divide Fires 2006/2007 and Black Saturday 2009, have all occurred during extended periods of drought.

Over time, fire regimes have been altered so that instead of regular, small, less intense fires, we now have larger, more infrequent and much more severe bushfires. The time intervals between fires in some regions have increased from an average of 20 years to up to 50 year time gaps between fires. The result has been some changes in habitat, with a reduction in plant diversity and a high build up of fuel in forests. This can result in a

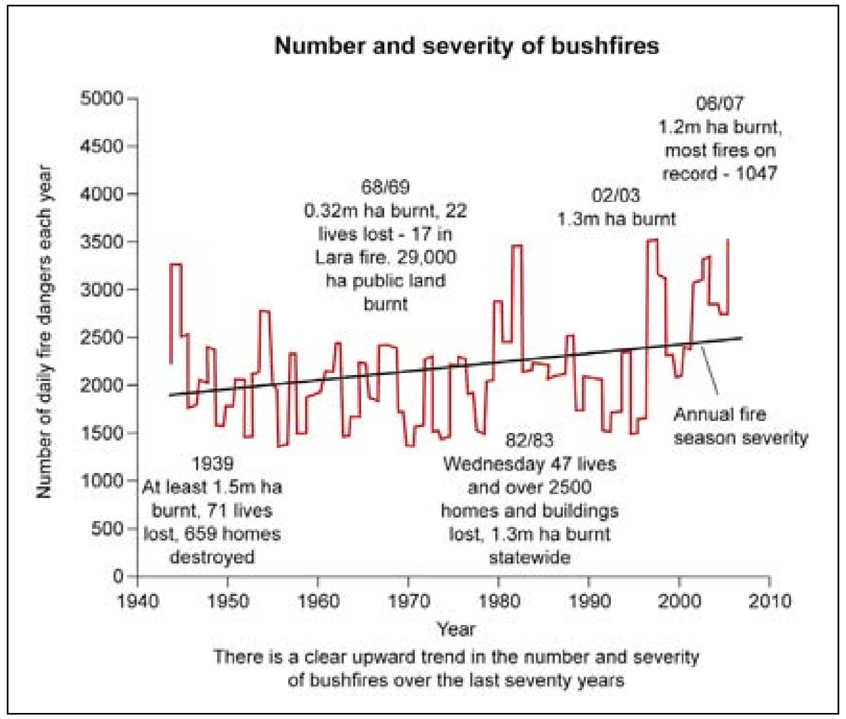

Figure 2.13: *The number and severity of bushfires*

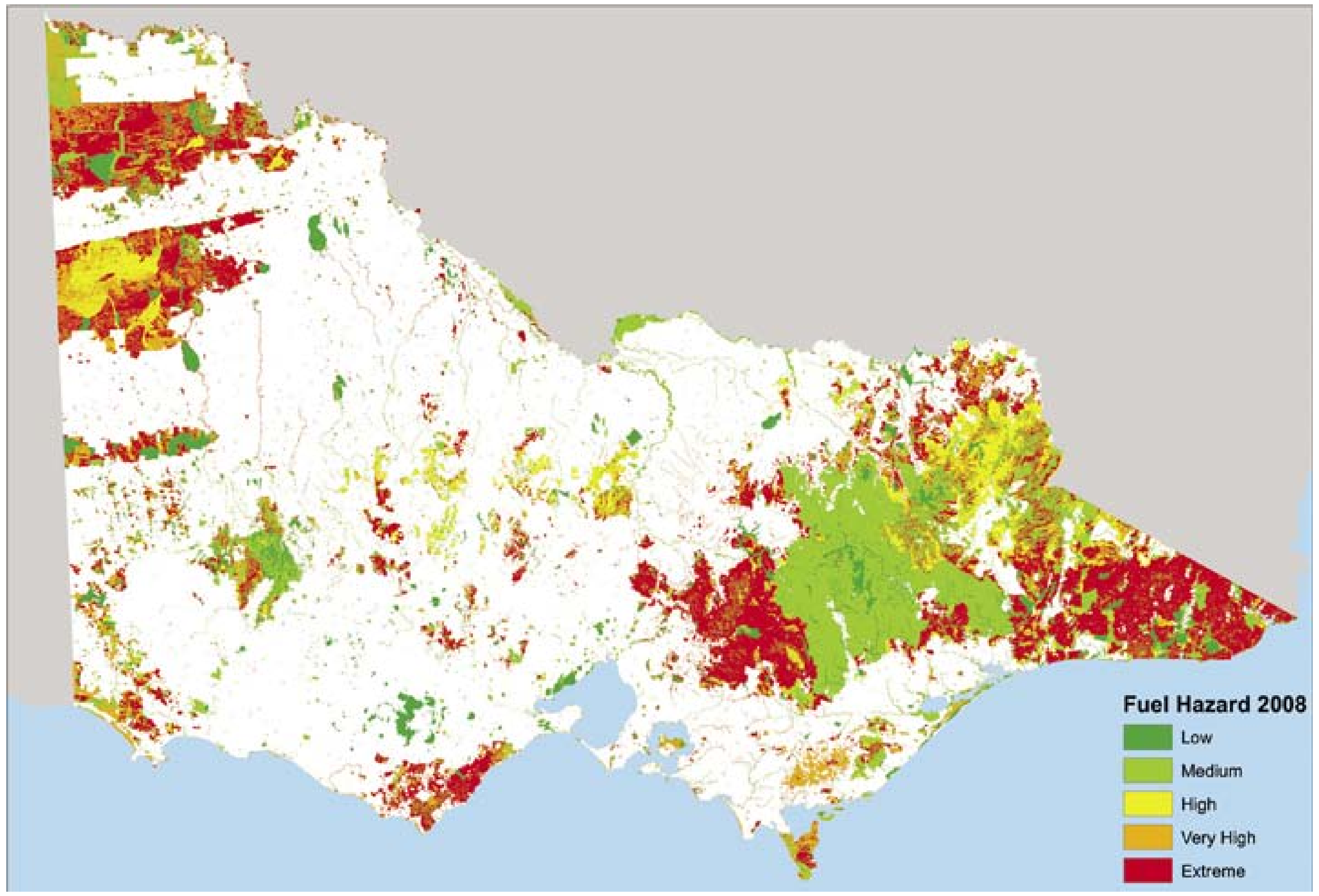

Figure 2.14: *Forest fuel hazard on public land for Victoria (2007)*

greater risk of severe fire and possibly permanent changes to ecosystems that do not experience regular fires.

The occurrence of infrequent, large and severe bushfires rather than more frequent, smaller, dispersed and less-intense fires has resulted in an imbalance of fire and less biodiversity across habitats and landscapes. This imbalance increases the risk of large fires and also the possibility that some ecosystems will permanently change if they burn too often or too intensely.

More than 80 per cent of Victoria's fires are contained as small fires of less than five hectares. The remaining 20 per cent of fires account for 90 per cent of the total area burnt each year.

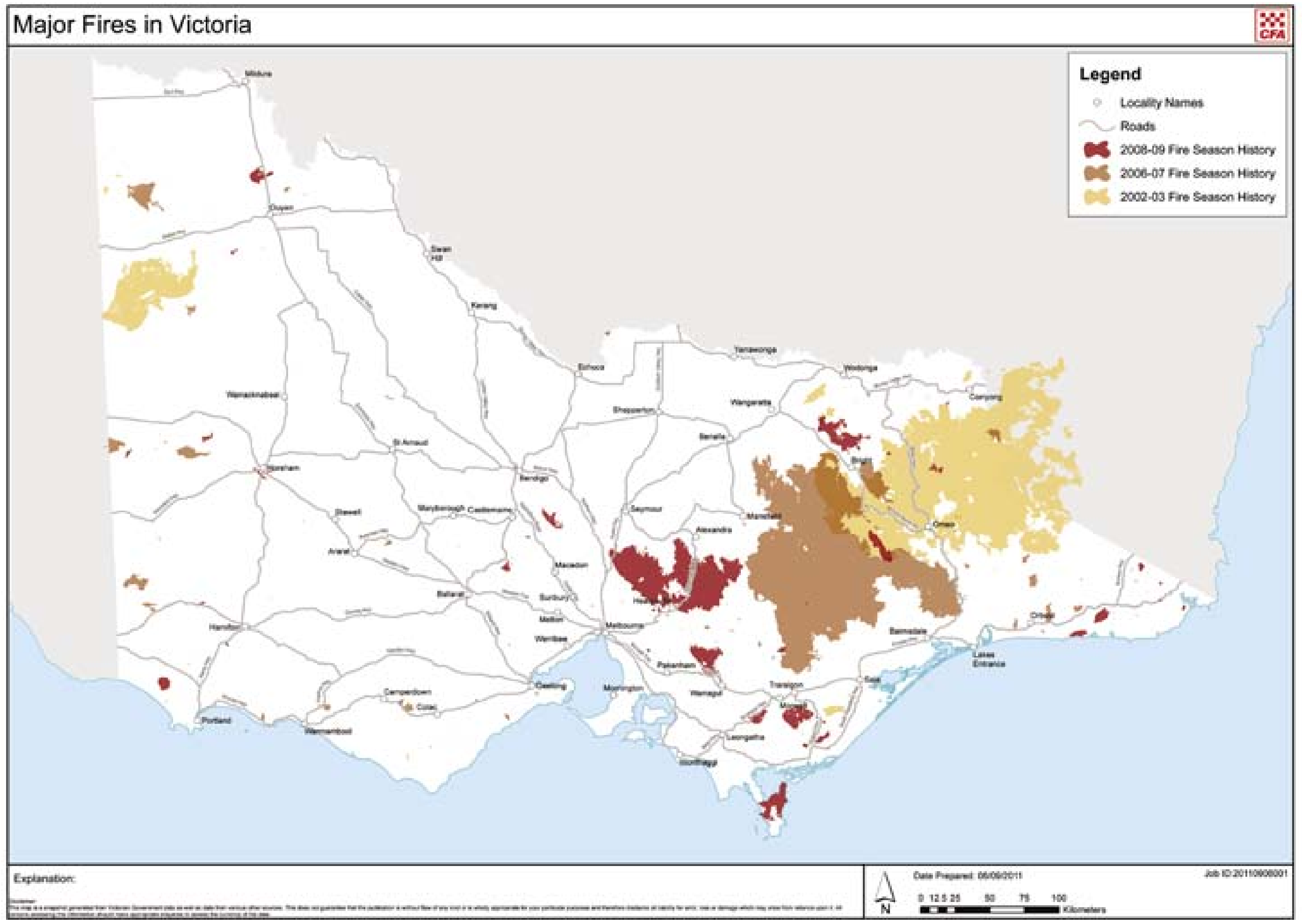

Figure 2.15: *The distribution and scale of bushfires for three select fire seasons*

c2

Activities

1. Which world region/s experienced widespread fires in August 2011? Use figure 2.2 to identify the possible main cause of these fires.

2. Study the information in figure 2.2. What appears to be the three most common causes of wildfire across the world's continents?

3. Identify similarities and differences in the way Indigenous Australians and early settlers used fire. Construct a table similar to the one below to complete your answer.

Fire as a resource	Indigenous Australians	Early settlers
Source of fire		
Domestic use		
Social use		
Economic use		
Effect on the environment		

4. Examine figure 2.4 and list the ways in which modern-day firefighting differs from the methods used by early settlers.

5. Refer to figure 2.16.

a. Estimate the approximate area of Victoria that was covered by forest in 1788 and in the 1990s.

b. How has the distribution of forests in Victoria changed over time? Where has there been the most/least change?

c. How would you explain the decrease in forest areas in Victoria?

d. Predict how changes in the area covered by forest might have affected the distribution and frequency of bushfires in Victoria.

6. a. Refer to the information provided in figures 2.6 and 2.7 to answer the following true/false statements.

i. Regions in Australia that have bushfires every five years or less are found in the south-east of the country.

ii. Areas of high population density generally experience a low risk of bushfire.

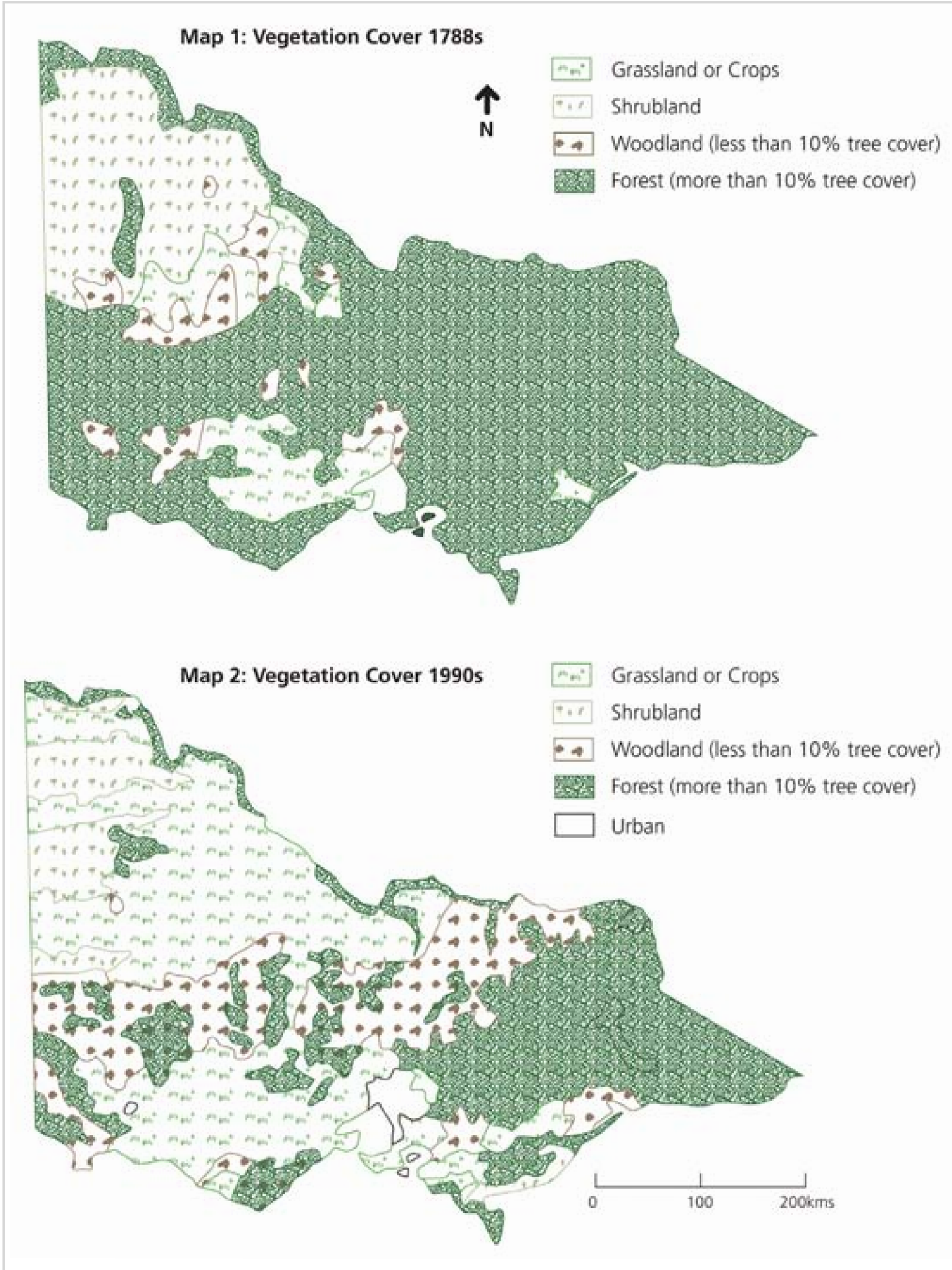

Figure 2.16: *Vegetation cover 1788 and 1990s*

iii. Over 90 per cent of the Northern Territory has a population density of less than one person per square kilometre and only a once in more than 20 year occurrence of bushfire.

iv. All the state and territory capital cities have at least a once in every 10 year's chance of a bushfire.

v. Bushfires can occur in all seasons in Australia.

vi. Bushfires in Victoria mostly occur in summer.

b. Re-write the incorrect statements so that they are accurate.

c. Describe the relationship between high bushfire occurrence and Australia's population distribution. Use data from the maps in your answer.

7. The graph in figure 2.13 shows the total number of days with fire danger warnings per year in Australia. Use the information in the graph to complete these statements.

a. This graph shows that the overall trend in the number of bushfire danger days from 1940 to 2010 is ________________

b. Between 1990 and the year 2000 the lowest number of fire danger days was ________________

c. ________________ was the year that recorded the most number of fire danger days, with ________________ days.

d. The Great Divide fires in the 06/07 fire season saw ________________ fire danger days.

e. In general, it can be seen that the years when the most severe fires occurred were also the years when ________________

8. Study figure 2.17 showing Australia's bushfire history from 1997 to 2008. Estimate the percentage of each state or territory that has been affected by fire over this time period. Record your data in a copy of the following table.

State or Territory	Percentage of area affected by fire
Australian Capital Territory	
New South Wales	
Northern Territory	
Queensland	
South Australia	
Tasmania	
Victoria	
Western Australia	

9. Research, using the internet, one of the following topics:

a. Research about and present other Indigenous Australian Dreamtime stories about fire (different from the one in figure 2.5). Your presentation should include artwork depicting your story or stories.

c. How fire is used for agriculture in one particular region of the world South America, Africa or South-East Asia?

d. Wildfires in the U.S.A.

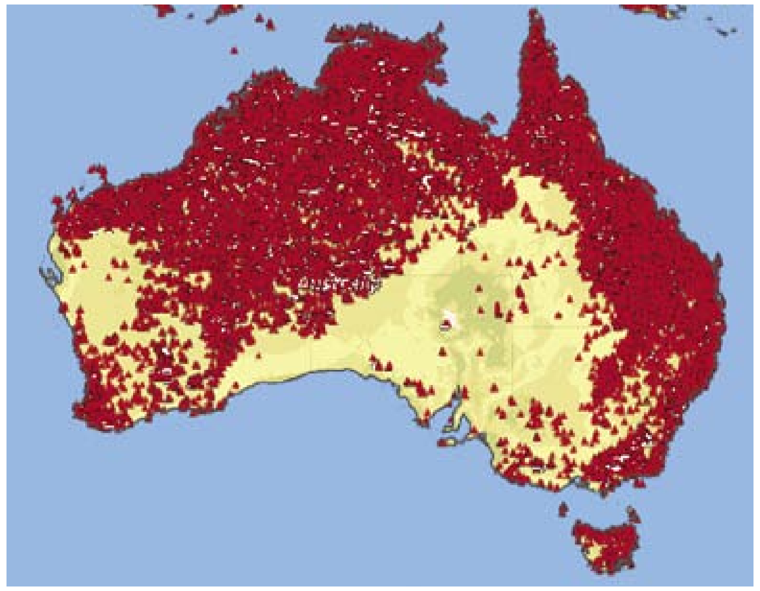

Figure 2.17: *Australia's bushfire history from 1997 to 2008*

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c3 How do bushfires behave?

Introduction

Understanding how a fire starts and burns does not tell us about the size of the fire, how fast it will spread and the potential damage it could cause. To understand how a bushfire behaves, we need to examine the factors that determine how a fire burns in the natural environment. These factors include: fuel, weather, topography and the nature of the fire itself. Diagrammatically, this is shown in figure 3.2.

Fire intensity

The intensity of a bushfire refers to the amount of heat it generates. The higher the intensity, the harder the fire is to control and the more damage it is likely to cause. Fire intensity is influenced by vegetation, weather and **topography,** or shape, of the land.

What factors affect bushfire behavior?

Fuel

Fuel is one of the most important factors that influences the way bushfires behave and move. Fuel is essentially everything that burns in a bushfire. Variations in fuel will also influence the risk to firefighter safety and determine how difficult it will be to control a fire. Common types of fuel involved in a bushfire include: grasses, forest litter lying on

Figure 3.1: *Bushfire on the horizon*

the ground, small shrubs, scrub, trees, logs, stumps and bark. Given the right conditions, most of these fuels will readily ignite and burn at differing rates and degrees of intensity.

There are four main characteristics of fuel which affect fire behavior:

1. **Moisture content** Fire behaviour is affected by how dry the fuel is. The moisture content will vary depending on such things as: weather conditions, type of vegetation and whether the fuel is living or dead. The lower the moisture content of the fuel, the more easily it burns. Dry grass, leaf litter and dry twigs have a lower moisture content than green plant material. Think about what happens if you try to light a bush barbeque with damp wood.

   A severe grassfire season usually follows a period of abundant winter and spring rains, which produce lush growth, followed by a relatively short, hot, dry period in summer, which then dries out the grass.

   Severe forest fire conditions are characterised by a substantial winter and spring drought that carries over

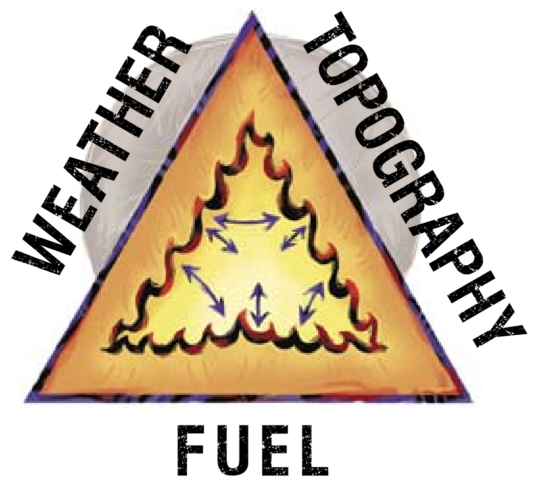


Figure 3.2: *Factors important in determining bushfire behaviour. Each element is affected by, and in turn affects, other elements*

Figure 3.3: *Long dry grasses collecting on a fence*

Figure 3.4: *High fuel loads building up in a forest*

into the summer. Under these conditions, not only are the fuel bed and large logs very dry, but also shallow lakes and streams—usually wet or green in a normal summer—dry out and become flammable.

2. **Quantity** The greater the quantity of fuel available, the larger the fire will be. The quantity of fuel is greater in long grass than in short grass, and greater again in forests where the leaf litter and undergrowth have built up over time (as can be seen in figure 3.4).

3. **Size** The smaller the fuel size, the more easily it will ignite and burn. Fuel is normally classified as fine or coarse in relation to its size.

   Fine fuels are less than six millimetres in diameter (smaller than the diameter of a pencil). They include twigs, grasses and some bark which can ignite and burn readily. Grassfires rarely persist for more than 10 seconds in one area but can spread quickly (up to 30 km/hr) and respond rapidly to changes in the weather.

   Coarse fuels are greater than 6 mm and include sticks, branches, logs and stumps. Coarse fuels tend to ignite less readily, burn slower and for much longer periods.

4. **Arrangement of fuel** The arrangement of the fuel affects how easily it will burn. Long grass standing upright (see figure 3.3), dries more quickly and is surrounded by oxygen. Compare this to moist compacted leaf litter on a shady forest floor where there is little oxygen. (Refer back to the fire triangle in figure 1.2.)

   When fuels are well separated, such as in sparse tussock grasslands, fire spread can be impeded because there is more distance between the tussocks.

   A continuous ladder of fine fuel from the ground surface to the crown of the vegetation, encourages the development of crown fires.

Figure 3.5: *A mixture of fine and coarse fuel in leaf litter*

Figure 3.6: *Ribbon bark seen on this tree could act as a fuel ladder in a bushfire*

Weather

Weather is a major factor that influences fire behavior. Major fires occur in Victoria on days when there is a strong, gusty, northerly wind coming from the hot, dry, desert interior of the continent. Bushfires are more likely to start or reach disaster conditions after an extended dry period or drought, when temperatures are high (e.g. 40ºC) humidity is low (e.g. 15 per cent) and wind speeds are high (e.g. 50 km/hr).

Weather is the term given for the meteorological features over a short period of time (e.g. day-to-day).

Climate The average conditions of the atmosphere over the long term for example where daily weather conditions are averaged over a long time.

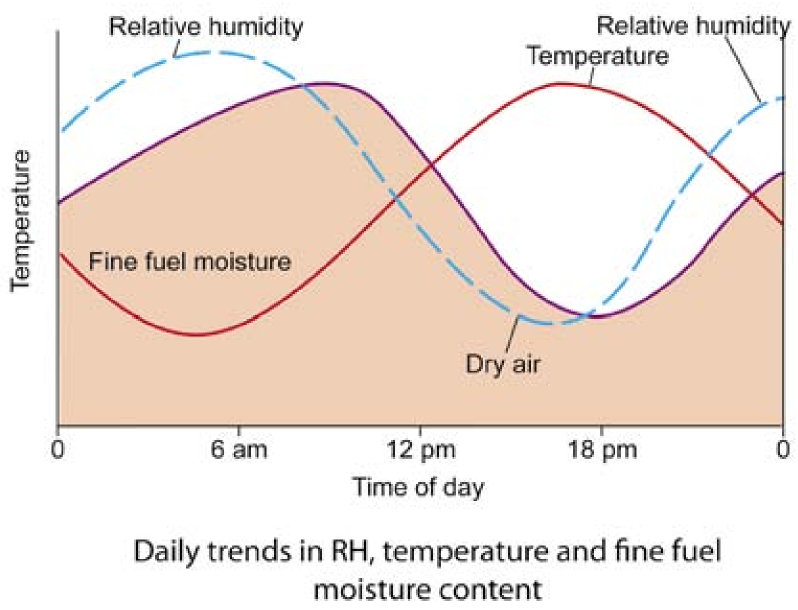


Figure 3.7: *Trends in relative humidity, temperature and fuel moisture over a 24 hour period*

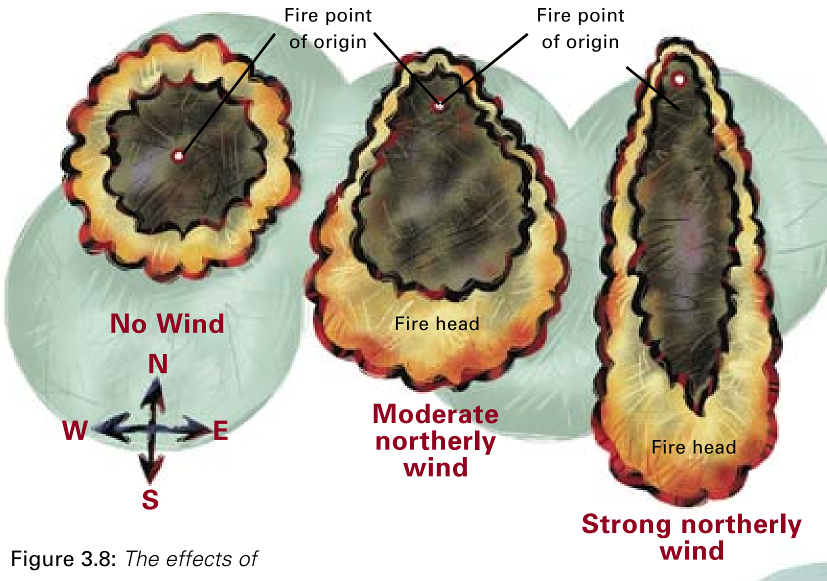


Figure 3.8: *The effects of wind strength and direction on fire shape*

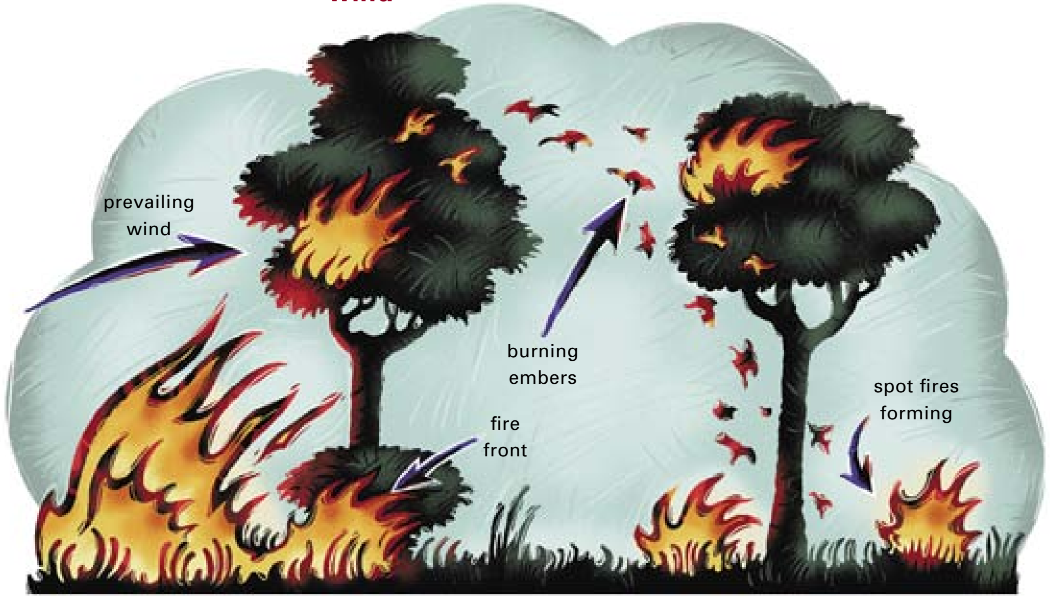


Figure 3.9: *The effect of wind and the formation of spot fires*

Air temperature The sun warms the air, land surface and available fuel, raising their temperatures. An increase in temperature, and the resulting decrease in **relative humidity**, will dry out fuel, making it easier to ignite. That is why more fires occur on hot days.

Relative humidity If there is high humidity, it will feel very hot and sticky. In Victoria, low humidity is usually experienced when there is a hot, dry north wind blowing. When humidity is low (i.e. less than 20 per cent) fuels will become drier and ignite more easily. They will also burn faster and more fiercely. In a bushfire situation, fire intensity usually increases during the day as the temperature rises and the relative humidity falls. It reduces at night as humidity increases and temperatures drop, as shown in figure 3.7.

Wind Wind is the most critical aspect affecting the shape, forward rate of spread and behavior of a bushfire. Wind is also important for supplying oxygen for the burning process and removing ash, smoke and moisture from fuels in the area. Another feature of wind is the fact that it can slant the flames so hot air and gases move ahead of the fire, preheating the fuel and allowing the fire to spread faster. Think about what happens when you blow on flames on dry wood in a fireplace?

Changes in wind direction and an increase in wind speed present serious hazards to firefighters.

> Winds are always named from the direction they are blowing. A northerly wind originates from the north and blows towards the south. The Bureau of Meteorology measures wind speed at 10 metres above the ground in an open area.

The speed or strength of a wind is a major cause of rapid change in fire behavior. It will affect the intensity of a fire, the speed at which it travels and its shape. The stronger the wind, the longer and narrower the fire will be. Figure 3.8 shows different shaped fires as a response to wind direction and strength.

The wind may also lift burning materials, such as bark and other embers, and carry them ahead of the front, starting spot fires. It was estimated that spot fires began blazes up to 35 km ahead of the front during the Black Saturday bushfires in February 2009.

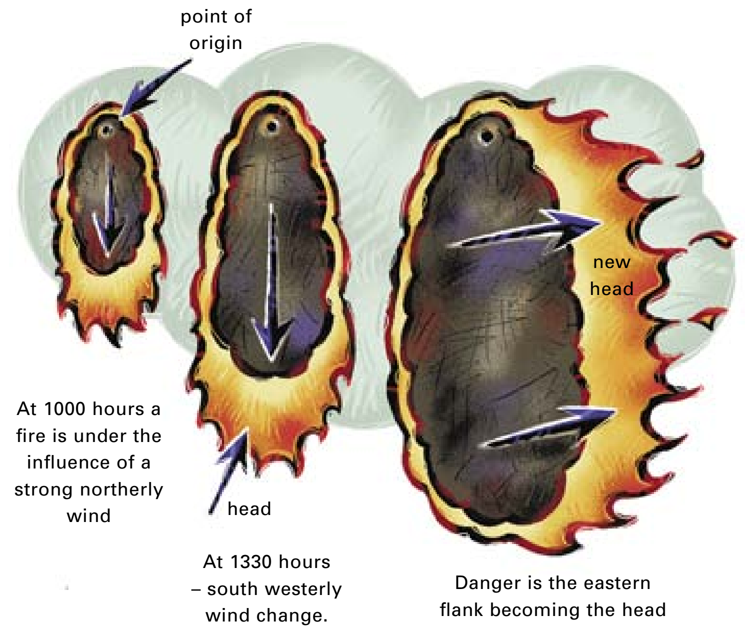


Figure 3.10: *The results of a change in wind direction on bushfires*

If a wind changes direction, then a relatively quiet fire flank can become the new head fire. Sudden and unexpected changes are especially dangerous as firefighters and people may be unprepared to deal with the new fire conditions. The following diagram illustrates the effect of wind change on a fire.

Figure 3.11: *Case study Ash Wednesday*

Case study: Ash Wednesday 1983

The importance of wind direction is demonstrated by the Ash Wednesday Fires of 1983.

On the day, the temperature was 43 degrees Celsius, the humidity was about 10 per cent, curing was 100 per cent and Victoria had recorded its driest 10 month period on record. Before the cold front arrived, the wind was 40–50 km/hr, gusting to 80 km/hr. The fire rating for these Ash Wednesday conditions was at a minimum of 70 and after the change it was off the scale at over 100.

In the late afternoon, a cold front swept across Victoria, bringing a welcome cool change. However, it caused the wind direction to swing around from the north to the south-west. What had previously been the side of the fire became the fire front. Firefighters are usually aware of expected wind changes when at a fire. They aim to put out the eastern side, or flank, of the fire before the change of wind direction occurs. However, on this day the change of wind direction trapped firefighters and residents in the new path of the fire.

A wind change is a common feature of bushfire disasters in Victoria. Hot, dry winds often come from the north and north-west and are often followed by a south-west wind change. In this situation, the side of a fire can quickly become a much larger fire front. Typically, about 80 per cent of the total area burnt is after a south-westerly wind change.

Atmospheric instability is a measure of how easy it is for a parcel of air to rise. In an unstable atmosphere it is easy for air to rise and thunderstorms may develop.

Atmospheric stability The upward (vertical) movement of **air masses**, that occur when hot air rises and is replaced by cooler air, is affected by atmospheric conditions. The difference in fire behavior under stable or unstable atmospheric conditions can be seen in figure 3.12 and the photographs (figures 3.13 and 3.14). Under extreme weather conditions, large **pyrocumulus clouds** may form which contain severe turbulence and may cause lightning which can then ignite bushfires.

Summer and autumn are the most dangerous times of the year for bushfires in south-east Australia. This is especially so when a strong cold front approaches a slow moving high in the Tasman Sea, causing very hot, dry north-westerly winds. As the cold front passes, the wind direction will often swing around 90 degrees and air temperatures will drop.

Stable atmospheric conditions	Unstable atmospheric conditions
Fire behaviour predictable	Fire behaviour unpredictable
Stratus (layered) clouds	Cumulus clouds (cotton wool appearance)
Smoke columns rise, flatten out and drift in prevailing wind direction	Smoke columns rise to great heights
Air clarity may be reduced due to haze	Winds are gusty and unpredictable (i.e. swirling and dusty)
Winds generally light and predictable strikes	Potential for thunderstorms and lightning

Figure 3.12: *Comparison of fire behavior under different atmospheric conditions*

Figure 3.13: *Stable atmosphere with smoke column rising and flattening out*

Figure 3.14: *Unstable atmosphere*

Figure 3.15: *Pyrocumulus clouds from the Black Saturday bushfires. This photograph was taken 35 km from the fire front. Cloud height was estimated to be 8500 metres above the ground.*

Figure 3.16: *Satellite image of fire plumes and cool front approaching south-eastern Victoria*

Figure 3.17: *Fire will travel quickly up slopes*

Figure 3.16 shows a satellite image of south-eastern Victoria on 7 February 2009. Wind direction can be easily identified from the direction of the smoke plumes. The band of cloud approaching from the south-west is the start of the cool change.

Topography

The third major factor that impacts the spread of fire is topography. Topography refers to the shape of the land and surface features of a location or region such as: mountains, hills, valleys and plains. The topography of an area will influence the direction and speed at which a fire will travel. The effects can be quite complex as topography will also affect local wind speed and direction. The three key influences of topography are: slope, aspect and the interaction between terrain, wind and elevation.

Slope will affect a fire's rate of spread. If a fire is moving up a slope, rather than across level ground, there will be a shorter distance for radiant heat to travel from the flames to the unburnt fuel ahead. Therefore, fuels that are up-slope from a fire will be preheated to their ignition temperature more quickly than on level ground.

A general rule of thumb is, for every 10 degree of up-slope—double the rate of spread. The opposite is true for a fire burning down-slope. For every 10 degree of down-slope—halve the rate of spread.

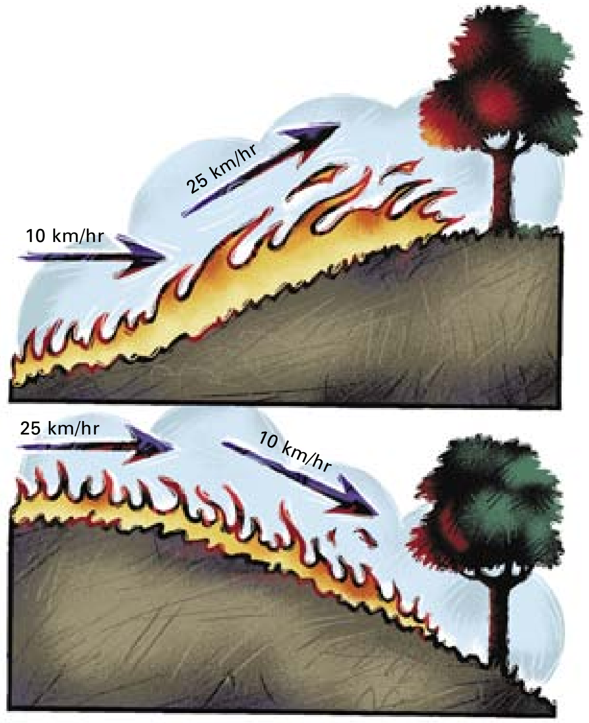


Figure 3.18: *The effect of slope on fire rate of spread*

Aspect is the direction that a slope or landform feature faces. This influences the amount of sunlight the land receives—northerly and westerly aspects (which receive more sun) will be warmer and drier than southerly or easterly aspects. Vegetation on these slopes will dry out more quickly and provide fuel for a fire.

Think of your own home. Which rooms are the hottest and which are the coolest? What is the aspect of your house?

Aspect will also influence the nature of the vegetation. For example, vegetation growing on a slope with a southerly aspect will tend to be more lush and less flammable than vegetation on more exposed slopes.

Terrain, wind and elevation The way that wind can interact with terrain can be quite complex. Exposed slopes and ridges may have increased wind speeds while sheltered, **leeside** slopes may experience calm conditions.

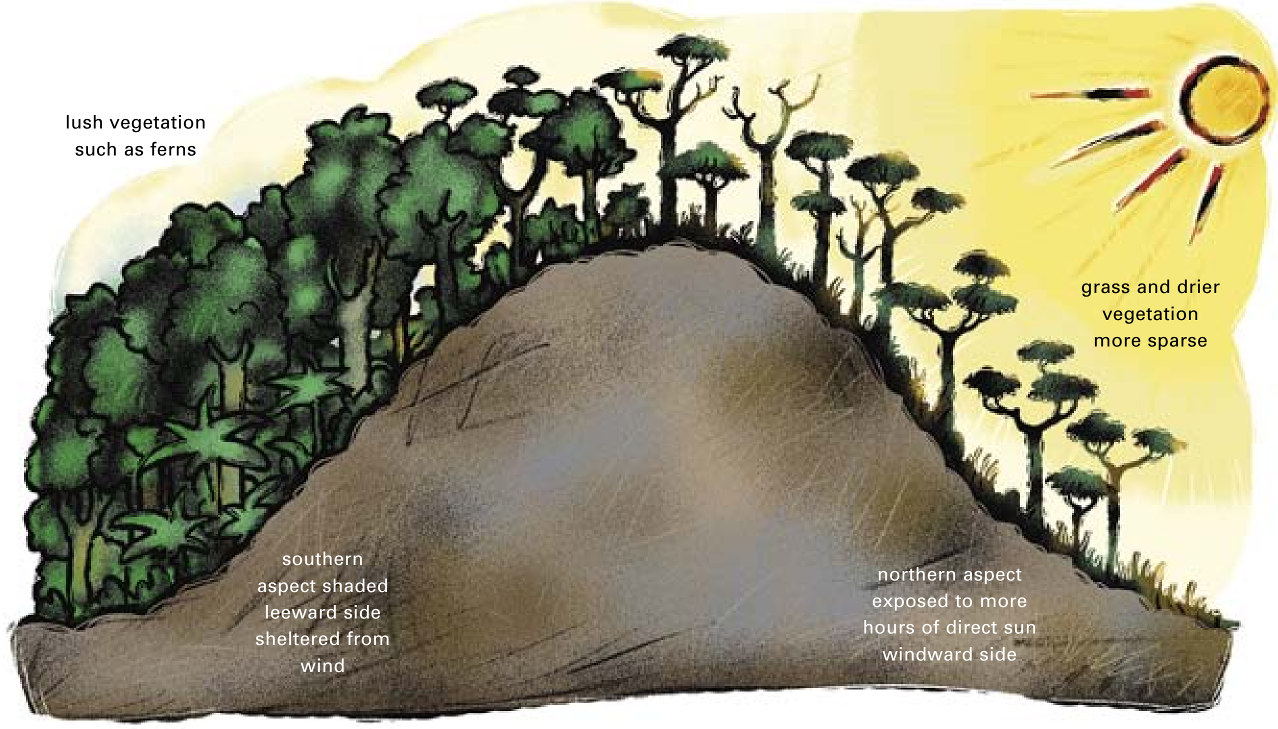


Figure 3.19: *Aspect and wind direction*

Figure 3.20: *Fire burning along a ridge on Mt Buffalo*

In mountainous country, winds tend to flow up or down valleys, irrespective of the general wind direction outside these areas. In fact, any change in terrain may affect wind direction. In coastal areas, afternoon sea breezes blow inland and may change fire direction.

Fire behavior may change significantly at different elevations (height above sea level). This may be due to changes in vegetation type, changes in temperature and humidity, as well as changes in wind speed and direction. This is particularly noticeable in alpine areas where fires may burn more intensely on slopes at night compared to during the day where fire intensity may increase in valleys. This is a result of changes in night time humidity levels.

Activities

1. Study figures 3.3 to 3.6 and make a list of the different types of fuel that you observe.

2. Refer to the text on page 43 and figure 3.6. Draw a labelled sketch or series of sketches to show how ladder-type fuel can spread a bushfire.

3. Study figure 3.21. Write a paragraph to describe the events of this fire in 1983. Use the following dot points as a guide:

- location of the start of the fire in relation to Lorne (use distance and direction)
- direction, time and distance covered before the cool change
- time of the cool change
- direction, time and distance of fire spread after the wind change
- estimation of total area burnt.

4. Use the data in the the table on the following page to create a temperature and humidity graph for Melbourne on 7 February 2009. A sample graph (figure 3.22) is provided for you. First plot the temperatures and then connect the points with a continuous line. Use a different colour pencil to plot and draw a line representing humidity readings. Label each axis clearly and write a suitable title for your completed graph.

5. Study your graph and answer the following questions:

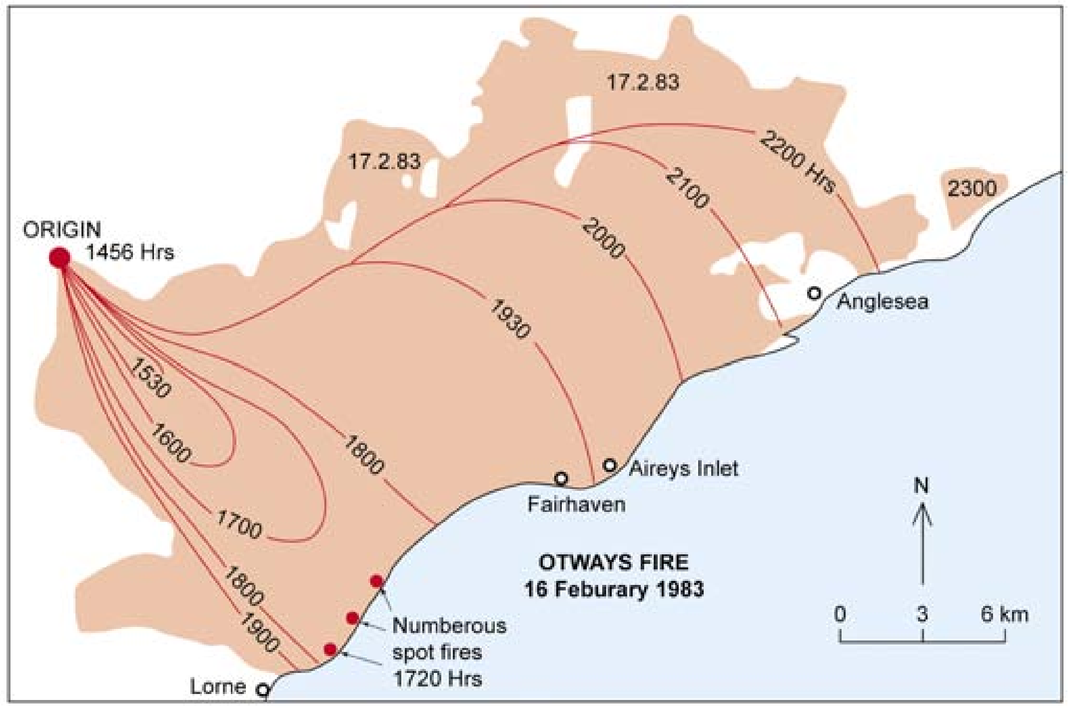


Figure 3.21: *Effects of change in wind direction. Otway Ranges, 16 February 1993*

a. What was the highest temperature recorded on the day? (Give the temperature and time.)

b. What was the lowest temperature recorded on the day?

c. What were the highest and lowest humidity readings recorded on the day?

d. At what times during the day on 7 February was it most dangerous for severe bushfires? Why?

e. Explain how high temperatures and low humidity increase the risk of bushfire.

Time	12 AM	2 AM	4 AM	6 AM	8 AM	10 AM	12PM	2 PM	4 PM	6 PM	8 PM	10 PM
Temperature °C	25.3	24.6	25.4	24.2	33.1	37.9	43.4	45.4	45.8	30.1	29.3	22.1
Relative Humidity %	43	40	51	56	23	16	9	6	5	45	38	77

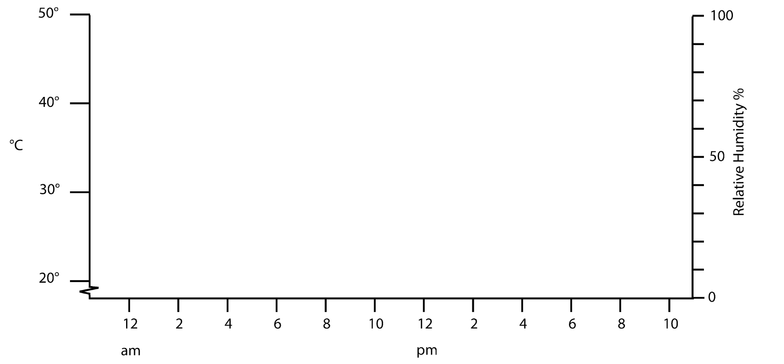


Figure 3.22: *Temperature and humidity data for Melbourne 7 February 2009*

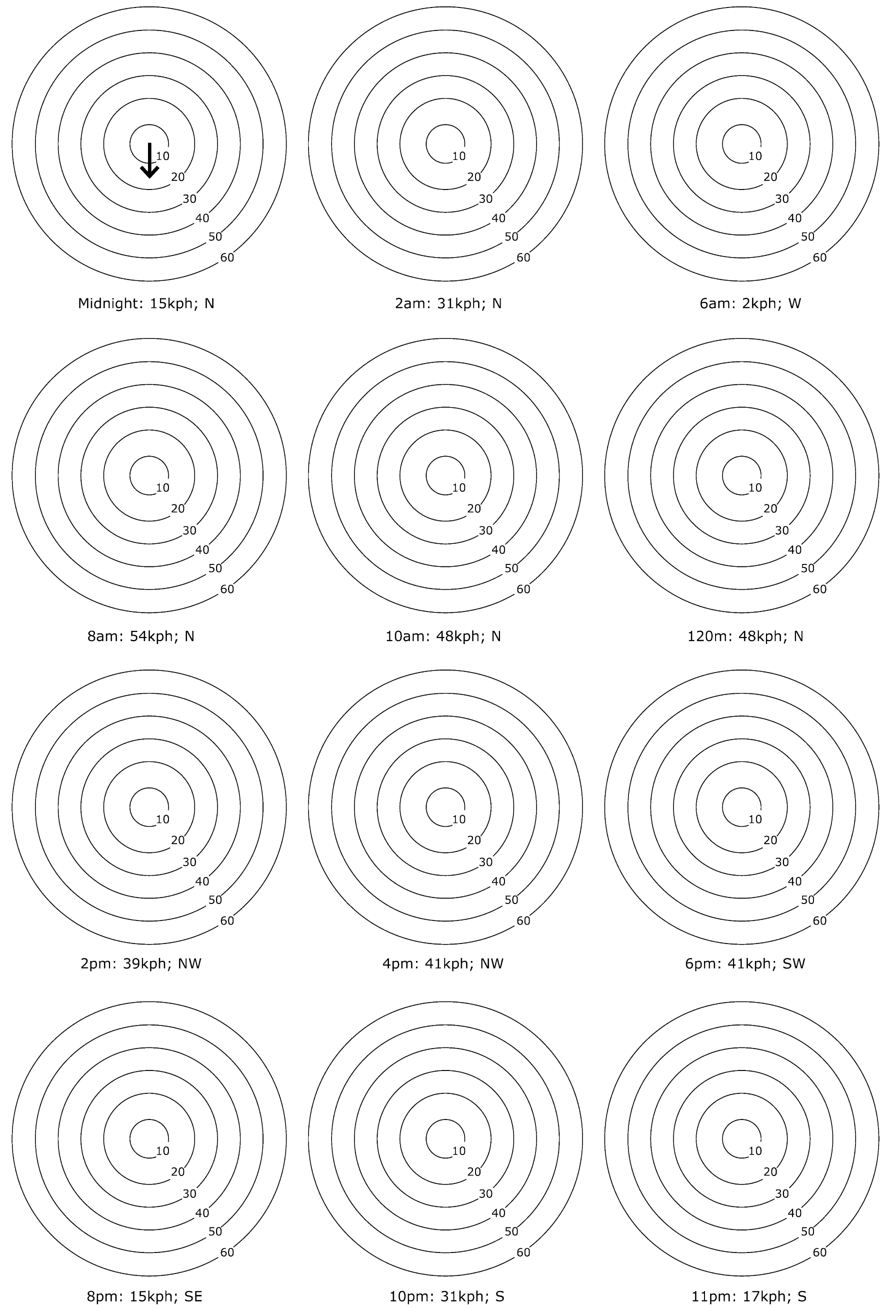


Figure 3.23: *Wind graph*

6. What were the wind strengths and directions for the Black Saturday fires? Make a copy of the following circle graphs (figure 3.23). For each of the time periods, draw an arrow to show wind direction. The length of the arrow should accurately represent the wind strength in kilometers per hour. The first graph has been completed and shows the wind blowing from the north at 15 km/hr.

7. a. What was the strongest wind speed recorded for the day and from which direction did it come?

b. What was the dominant or prevailing wind direction for the day?

c. In what ways did wind change during the day?

8. a. Using the knowledge you have gained from reading this chapter, create a web map to describe the worst possible conditions for a bushfire.

b. Make a copy of figure 3.24 on a sheet of A4 paper and use the sub-headings as prompts to write dot point notes on what conditions would produce a disastrous bushfire?

Figure 3.24 *Flow diagram*

Case Study: Black Saturday bushfire weather

Introduction

Saturday, 7 February 2009 has become known as Black Saturday—the day of Australia's worst bushfire and our biggest natural disaster in 110 years. On that day, 173 people lost their lives, over 2300 homes were destroyed leaving almost 8000 people homeless, and almost half a million hectares of Victoria was burnt.

Date	Type of disaster	Location	Impacts
1899	Cyclone Mahina	Cape York, Queensland	400 people died. Loss of over 100 pearling vessels
2009	Black Saturday bushfire	Victoria	173 people died. 2300 homes destroyed. Almost half a million hectares burnt.
1918	Cyclone (unnamed)	Innisfail and north-east Queensland	90 deaths. Extensive damage to town and countryside
1852	Gundagai floods	southern NSW	89 deaths
1983	Ash Wednesday Bushfires	Victoria and South Australia	75 deaths. 2000 houses destroyed in Victoria
1934	Cyclone (unnamed)	Cape Tribulation, Northern Queensland	75 deaths. Pearling fleet devastated
1939	Black Friday Bushfires	Victoria	71 deaths. 2 million hectares of land burnt
1974	Cyclone Tracy	Darwin, Northern Territory	64 deaths. City of Darwin flattened. More than 20 000 left homeless
1967	Tasmanian Bushfires	Hobart and southern Tasmania	62 deaths. 1400 homes destroyed. 264 000 hectares burnt in just five hours

Figure 3.25: Australia's worst natural disasters (does not include man-made disasters)

In early 2009 the bushfire season was in full force. By New Year's Day, there were seven fires burning in public parks and forests. The number of fires rose to 29 on 14 January and doubled to 58 by 25 January. Fire numbers continued to rise to 125 in the week before Black Saturday. On 7 February around 400 bushfires started, nine of which became major fires. Figure 3.26 lists the key fires ignited on 7 February and figure 2.15 (page 35) shows the location of these fires.

Figure 3.26: *Fires burning on 7 February 2009*

Fires ignited on 7 Feb 2009	Reporting of fire	Reported ignition source	Land tenure at ignition	Total area affected (ha)
Bunyip	04.02.09	Arson	State Park	26,200
Kilmore East	11:50am	Power line	Private property	127,676
Horsham	12:26pm	Power line	Private property	2,200
Coleraine	12:36pm	Power line	Private property	775
Weerite	1:17pm	Power line	Private property	1,300
Churchill	1:33pm	Arson	Plantation	24,500
Murrindindi	2:57pm	Unknown	Private property	131,712
Redesdale	3:11pm	Unconfirmed	Private property	9,500
Bendigo	4:34pm	Arson	Private property	330
Erica	6:00pm	Lightning	State forest	1,778
Beechworth	6:09pm	Powerline	State forest / private property	31,000
Dargo	N/A	Lightning	State forest	13,640
Mt Riddell	N/A	Lightning	National Park	Part of Kilmore East
Total	-	-	-	**370,611**

Why were these fires so severe?

Climate Victoria recorded the warmest temperatures on record in the decade of 1999–2009 (figure 3.27). With most of the state receiving well below average rainfall during the same period (figure 3.28), the whole of south-east Australia was suffering from a severe and prolonged drought. Such a drought had led to the death of many plant communities adding to the build-up of combustible material in forests and parks.

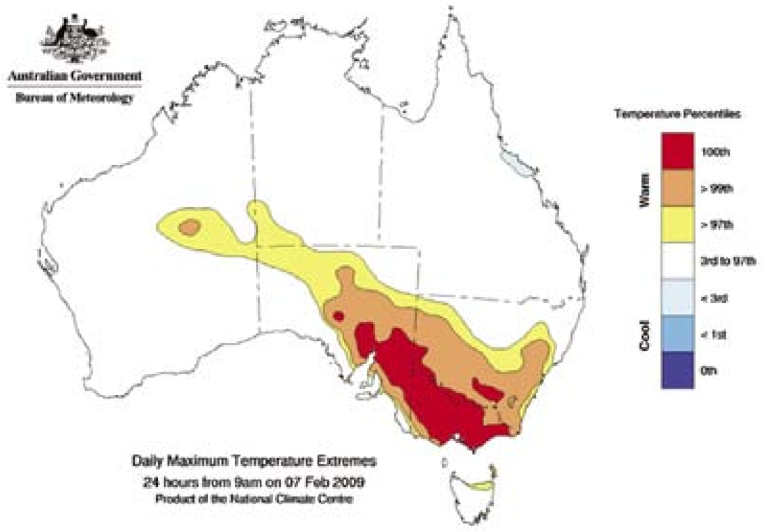


Figure 3.27: *Daily maximum temperature extremes*

Weather During the final week of January, Victoria experienced one of the most severe and prolonged heatwaves in south-east Australia's recorded history. Over much of central, southern and western Victoria, maximum temperatures reached their highest recorded levels since 1939.

Maximum daily temperatures for Melbourne were near or exceeding 30°C for the 11 days prior to Black Saturday. Melbourne broke a record with three consecutive days of over 43°C. This heatwave dried out vegetation further, making it more combustible.

The amount of moisture in the air was also extremely low. The relative humidity was less than 10 per cent for several hours. This also contributed to the drying out of fuels.

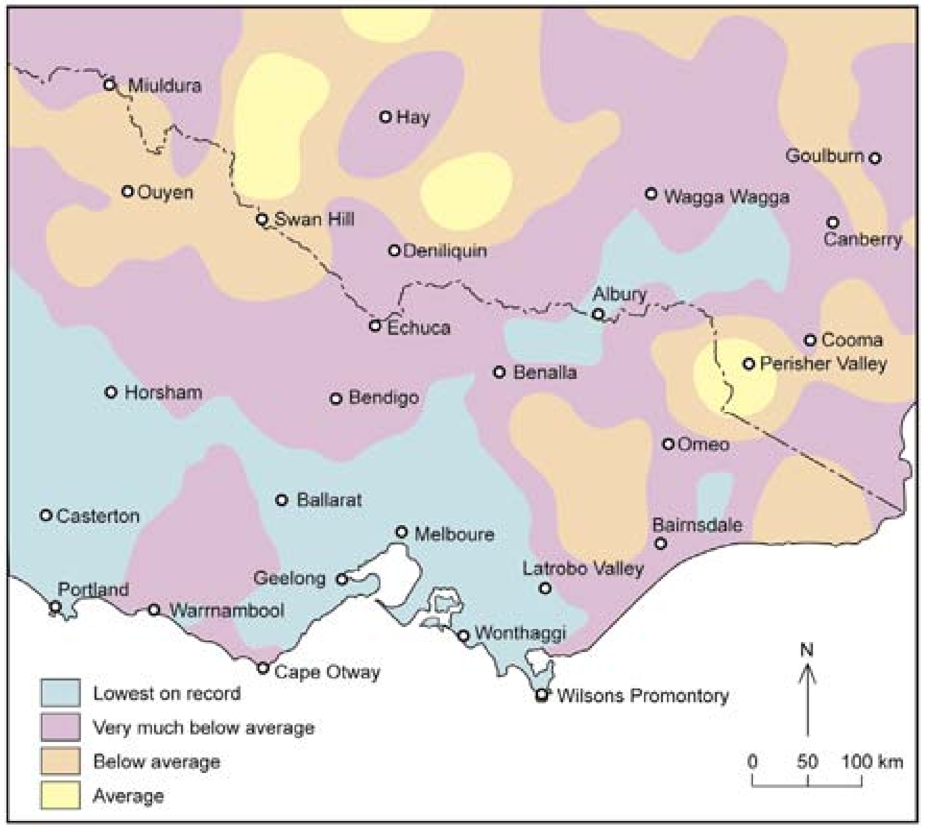
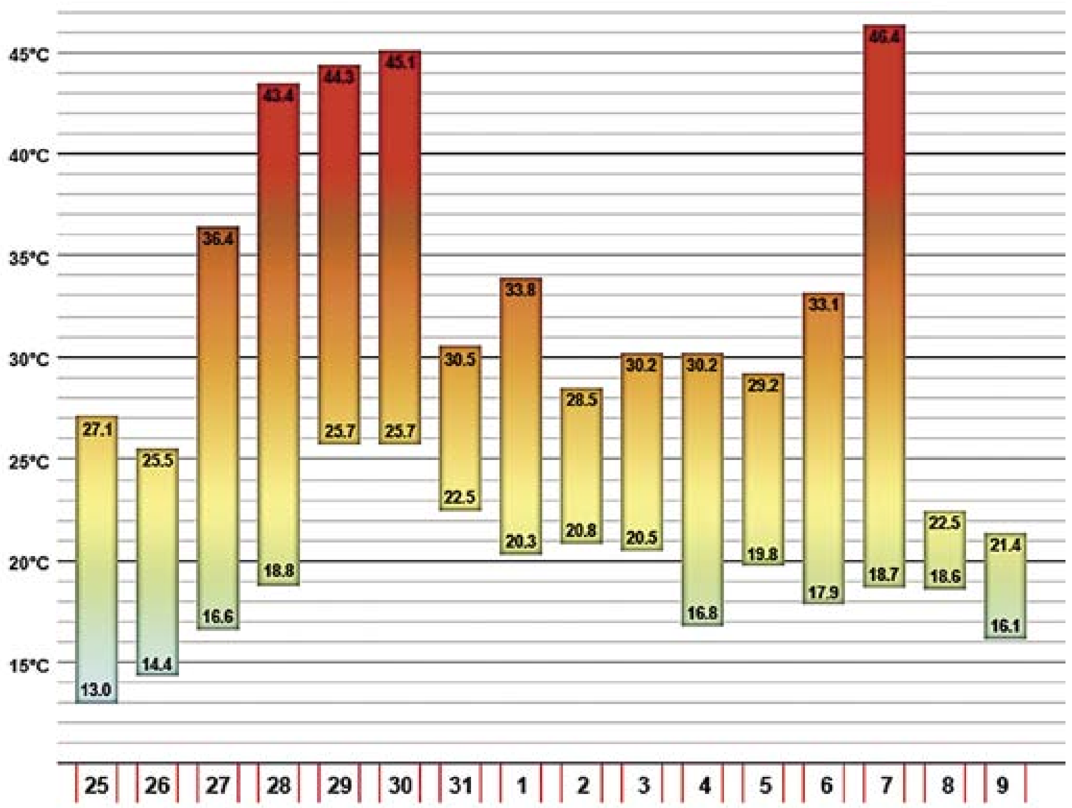


Figure 3.28: *Rainfall for Victoria 1/2/1997 to 31/1/2009*

Figure 3.29: *Record highest January maximum temperatures*

Site	Max temp record high		Previous max temp record high			Average max temp
	(°C)	Date	(°C)	Date	Years of record	(°C)
Wilsons Prom lighthouse	41.4	29/1/09	41.1	18/1/1959	53	20.5
Maryborough	43.5	29/1/09	43.3	25/1/2003	42	28.4
Heywood Forestry	43.2	29/1/09	42.7	02/1/1991	41	23.9
Wonthaggi	43.7	29/1/09	43.0	24/1/1982	40	23.7
Moorabbin airport	44.9	29/1/09	44.3	25/1/2003	37	25.6
Scoresby Research Institute	43.8	29/1/09	42.8	25/1/2003	37	26.1
Bundoora (Latrobe Uni)	44.3	29/1/09	43.8	25/1/2003	30	26.2
Hamilton airport	44.0	29/1/09	42.6	25/1/2003	26	26.0
Morwell (Latrobe Valley airport)	44.5	29/1/09	43.2	25/1/2003	23	25.8
Grovedale (Geelong airport)	45.3	29/1/09	44.8	25/1/2003	21	24.6
Mt Buller	27.9	29/1/09	27.5	15/1/1988	20	16.9

Figure 3.30: *Maximum and minimum temperatures for Melbourne from 25 January to 9 February 2009*



On 7 February 2009, a low-pressure trough passed over the fire area ahead of a cold front. This created a very unstable air mass which enhanced the development of smoke plumes. These led to the formation of pyrocumulus clouds, which created thunderstorms and lightning.

On the evening of 6 February, a high-pressure system in the Tasman Sea caused very hot north-westerly air flows over much of Victoria. By the morning, these winds were reaching gale force strength. Strong winds fanned the flames and set off further spot fires, some up to 35 km ahead of the main fire. The start of a cold front, around 12.30pm saw the winds shift to a strong, gusty south-westerly. Temperatures started to drop and humidity increased as the front passed over the state. The fires changed direction rapidly after the wind change, especially in the eastern part of the state. It was then that the most severe fires were at their most savage. Prevailing winds on Black Saturday averaged 50–60 km/hr.

Topography The Black Saturday fires burnt in areas which differed in elevation by over 1000 metres. They included all types of landforms, from plains and valleys, to gentle and steep mountain slopes. An important feature of topography is the way winds changes with elevation, both in terms of speed and direction. The Churchill fires in south Gippsland raced up the slopes of the Strzelecki Range and the stronger winds at the top were able to blow firebrands down to the Yarram area, over 23 km away. The photograph in figure 3.32, shows the effects of strong winds, in excess of 120 km/hr, which funnelled through a gully during the Bunyip Ridge fire, snapping off trees.

Fuel There was an extensive range of vegetation across the fire region ranging from grassland to dry forest and rainforest. Due to drought conditions many forest areas that normally would have been too moist to burn, had dried out and burnt easily. Woody fuels had built up to high levels in wet mountain forests. Some species of eucalypts, for example

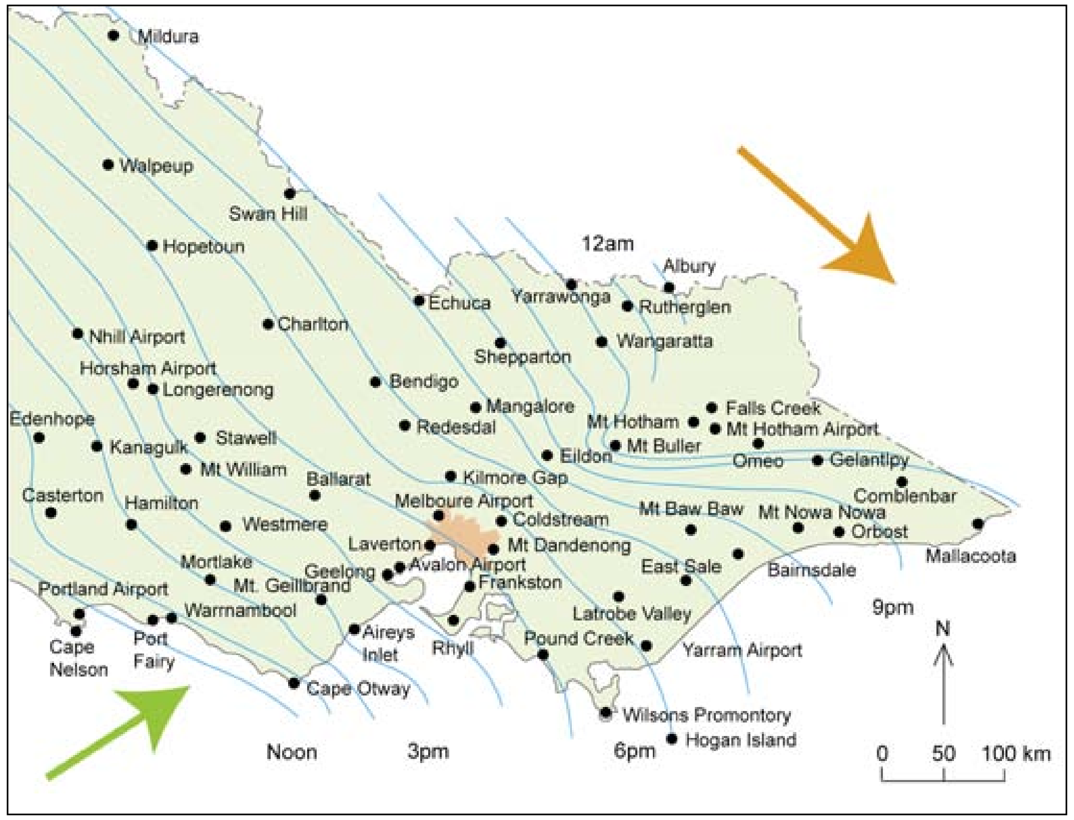


Figure 3.31: *Progress of the wind change, 7 February 2009*

mountain ash trees, have long ribbons of bark that hang off the branches and trunk. These were ignited and easily blown by winds.

Smoke It was extremely difficult to identify the head of many of the fires that burnt that day as they were frequently obscured by smoke. Often their location was not known until buildings or properties were alight. In addition, many of the fires did not burn in an orderly pattern. A great number of spot fires started, increasing the spread of destruction.

Figure 3.32: *Trees snapped by fire-induced winds*

Figure 3.33: *Flames were observed at up to 100 m in height with temperatures ranging from 900–1200°C*

The amount of heat released from just a few hours of the Black Saturday fires would have been sufficient to provide all Victorian domestic and industrial energy needs for a year. The energy of the fires was equivalent to more than 1500 atomic bombs similar to the one that devastated Hiroshima. It should be noted, however, that bushfires release their energy as a storm rather than a blast.

Source: Dr Kevin Tolhurst, *Comparing the 1939 and 2009 fires*, Melbourne University, 2009

The Fire Danger Index (FDI) measures humidity, wind speed, temperature and the combustibility of fuel at a given time and place. It rates the risk of bushfire on a scale of 0–100. Total Fire Ban days are triggered at 50. On Black Friday in 1939, the FDI was 100. On 7 February 2009, the FDI exceeded 150 in central Victoria and reached 189 in Kilmore.

Category	**Fire Danger Index**
Code Red	100+
Extreme	75–100
Severe	50–75
Very high	25–50
High	12–25
Low to moderate	0–12

Figure 3.35: *Summary of weather and Fire Danger Indices for selected Victorian Fires*

	Max Temp (°C)	**Min RH** (%)	**Wind speed** (km/h)	**Forest FDI**	**Grass FDI**
Black Saturday, Feb 7 2009, Victoria	46	4	51 (69)	172	241
Ash Wednesday, Feb 16 1983, Vic/SA	41	14	60 (90)	120	196
Black Friday, Jan 13 1939, Victoria	46	8	35 (65)	100	87
January 8 1969, Victoria	40	10	45 (90)	97	114
January 14 1944, Victoria	40	10	35 (55)	77	69
February 14 1926, Victoria	38	15	40 (75)	70	72
Alpine Fires, Jan/Feb 2003, Vic/NSW (ACT)	35	10	35	63	57

Figure 3.34: *Fire Danger Index for selected disasters*

The Murrindindi Fire

Murrindindi is a small settlement located approximately 100 km north-east of Melbourne. The fire started at 2.55pm to the north of a saw mill in Wihelmina Falls Rd. It travelled rapidly and was soon at Narbethong. Topography in the region consisted of a major north–south river valley with north–south mountain ridges to both the east and west.

Following a wind change that arrived at 6.15pm the fire changed direction and swept through the communities of Buxton, Marysville and Taggerty. It continued to burn for weeks in heavily forested public land and was not formally declared contained until March 5. By this time, the fire had merged with the Kilmore East fire and had burnt a total of 168 542 hectares. The development of the fire plume can be seen in the following sequence of photographs.

Source: Victorian Bushfire Royal Commission

Figure 3.36: *The Murrindindi fire plume grows*

Time	Event	Distance/ Speed	Location	Description
14.55	Fire ignition	Two km in first five minutes	6 km south-east of Murrindindi	Strong north-westerly winds fan fires across paddocks, through a blue gum plantation and into Toolangi State Forest. Predominant vegetation: mountain ash forest with ribbon bark and fuel load of 50 t/ha. Large convection column forms.
16.15	Rapid spread Lightning strikes recorded from this time until 21.48	12 km from start point travelling approx 11 km/hr	Black Range Spot fires around Granton, Narbethong, St Fillians and Mt Gordon	Fire is a combination of a rolling ground and crown fire, combined with spot fires to the south and east of main front. From the top of the Black Range, winds propel burning bark and leaves a further 15 km east. Spot fires close to main fire quickly become part of it while those further away behave independently and even start their own spot fires to the south-east.
18.15–18.45	South-westerly wind change at about 35–45 km/hr	Main fire front five km wide and north-east flank 40 km long	Narbethong and near Marysville	As the wind shifts to the south-west the north-east flank becomes the main fire front. Spot fires develop around and within Marysville. Spot fires in Narbethong join and burn towards Marysville.
19.15		Fire now moving in a north-east direction at five km/hr	Fire front moves through Marysville and then the Acheron River valley between Narbethong and Taggerty. Then through Buxton and the Steavenson River valley between Marysville and Buxton	Wind change increases fire intensity along north-east flank as far back as the point of origin.
22.00	Wind speed and FDI dropping		South of Taggerty	Despite changes in weather the fire had generated so much energy it cannot yet be contained.
Early hours of 8/2/09	Murrindindi and Kilmore East fires merge			First changes in fire behaviour observed.
5/3/09	Fire officially declared contained			

Figure 3.37 *Development of the Murrindindi fires 7 February 2009*

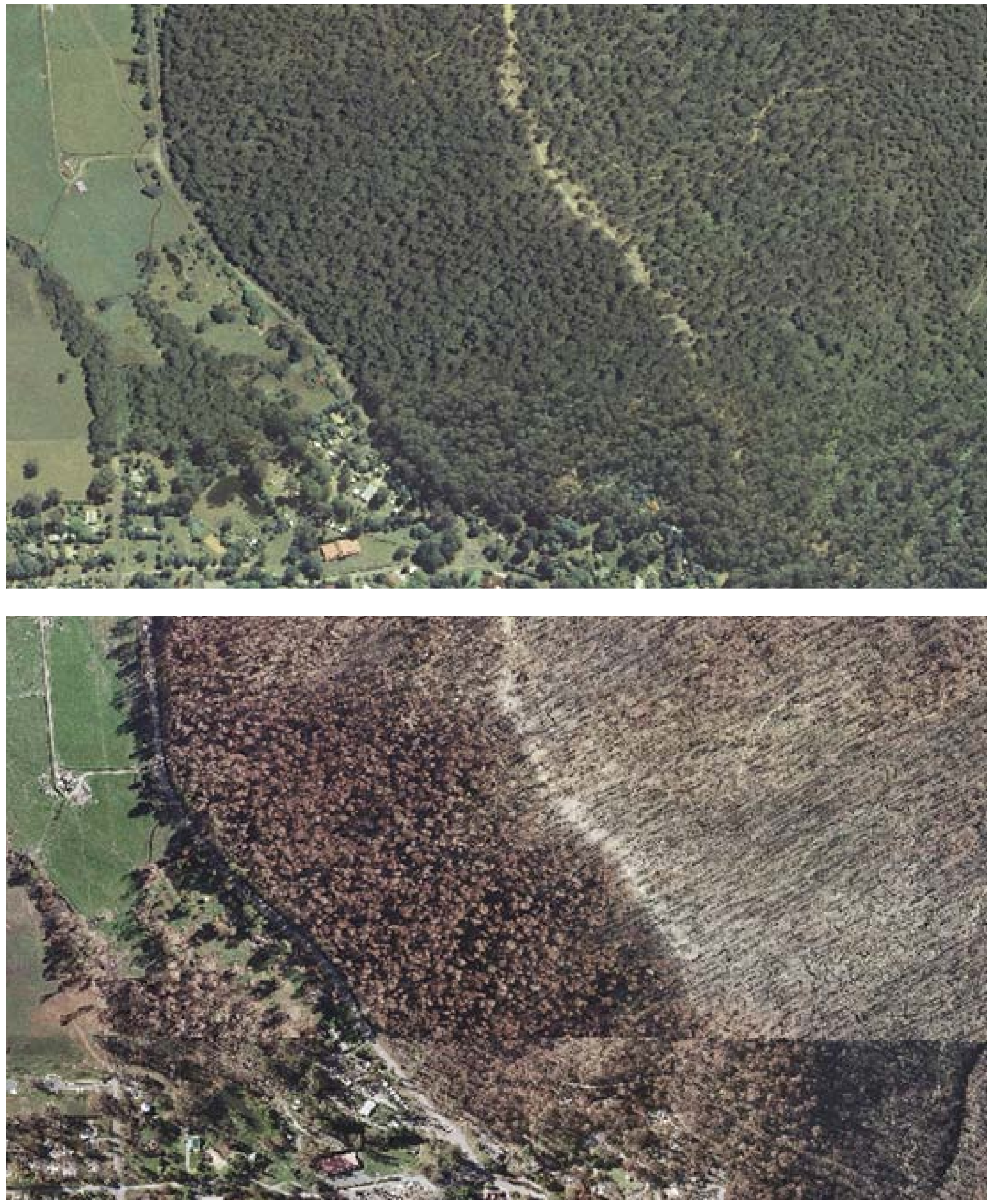


Figure 3.38: *Aerial photographs of Marysville before and after the fire*

The fire resulted in the deaths of 40 people and more than 400 houses were destroyed or damaged, mainly in and around Marysville, Narbethong and Buxton. The commercial centre of Marysville was destroyed, and along with it the core of the town's economic activity in tourism and hospitality. Much of the town's public infrastructure—including the police station, primary school, kindergarten and health clinic—was also destroyed. Figure 3.38 shows an aerial perspective of part of Marysville burnt by the fire.

c3

Activities

1. a. Examine the data provided in figure 3.25. What are the most common types of major natural disasters listed?

b. What types of natural disasters are missing from this list? Can you suggest reasons for this?

2. a. Using the data provided in figure 3.26 and figure 3.27, create an overlay to map the causes of the major fires. Follow these instructions to create your overlay:

i. Attach a sheet of tracing paper over the map of fires in figure 3.39.

ii. Trace the outlines of the fires onto the tracing paper. Using small, neat writing, name the fires.

iii. Devise a series of small, neat symbols to represent the different causes of fire and then map these for each of the fires.

iv. Draw a small circle around each symbol using one colour for human causes and a different colour for natural causes. Create a legend to explain your symbols.

v. Complete your map with a border, orientation arrow, legend, title, scale and source (where the data came from). Attach your map to plain white paper or your workbook.

b. Study your completed map and the write three sentences that summarise your observations.

3. a. Study the two maps, figure 3.27 and 3.28 showing temperature extremes and rainfall. Create two pie graphs to show:

i. the approximate percentage of Victoria that experienced the 100th, 99th and 97th maximum temperature percentiles on the day of Black Saturday

ii. the approximate percentage of Victoria having lowest, very much below average, below average and average rainfall for the 10 years from 1997–2007

iii. complete your graphs with titles and legends.

c. 'By February 2009, Victoria was a bushfire disaster waiting to happen'. Would you agree or disagree with this statement? Give reasons for your opinion and support with evidence from the graphs.

4. Examine the graph of maximum and minimum temperatures for Melbourne (figure 3.30) from 25 January to 9 February. Complete the following sentences by filling in the missing information.

a. Over this time period Melbourne had ________ days where the maximum temperatures were over 30ºC.

Figure 3.39: *Distribution of major fires, February 7 2009*

b. Minimum temperatures for this period only dropped below 15ºC on ________ days.

c. The diurnal range (difference between maximum and minimum for one day) for February 7 was ________________

d. The day that had the lowest diurnal range was ________

5. Figure 3.31 maps the progress of the wind change on 7 February 2009. Using distances, direction, times and place names, describe the progress of the cool change. Also refer to the timeline of events in figure 3.37.

6. Explain how the influence of the topography and weather conditions on 7 February contributed to the severity of the Murrindindi fires.

7. a. Did the cool change help or hinder the spread of the Murrindindi fires? Explain your answer.

b. How would a change in wind direction affect firefighting?

8. a. Would the fire have behaved differently if the dominant vegetation had been grassland rather than forest? Justify your answer.

b. Why did the fire take so long to be officially contained?

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www.royalcomission.vic.gov.au Final documents:
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Vol 1: The Fires and Fire Related Deaths, Chapter 10: The Murrindindi Fires
Vol 4: The Statements of Lay Witnesses.

What are the impacts of fire on the natural environment?

C4

Introduction

Fire has been present on the Australian continent for millions of years. Many plants and animals have evolved to survive fire events and have developed specialised relationships with fire.

Most forest and woodlands in south-eastern Australia have a similar structure. They are made up of a number of layers. The top layer is generally composed of large eucalypt species. The understorey is usually made up of: acacias (wattles), other small trees, tree ferns, shrubs, and tussock grasses. The ground cover often includes: various grasses, ground ferns and herbs.

The long-term effect of fire on a landscape varies according to sequences of fire events rather than to a single fire event. Sequences of fire events are known as fire regimes and are determined by three factors: intensity (how severe fires are), frequency (how often fires occur) and season (the time of the year that fires occur). Fires affect: vegetation, animals, soil and water in the natural environment.

Figure 4.1: *The impact of a bushfire*

Vegetation

Vegetation and the ecosystems they belong to can be affected by fire in a number of ways, as shown in figure 4.2.

Figure 4.2: *Effects of fire on vegetation*

Environment type	Effects of a high intensity fire	Effects of a low intensity fire
Fallen limbs and logs	Most consumed by fire	Most not consumed
Grass and other vegetation	Above-ground parts totally consumed	Above-ground parts mostly consumed
Shrubs	Above-ground parts totally consumed	Short shrubs consumed. Above-ground parts of tall shrubs may be killed
Tree trunks	Loose and surface bark consumed	Loose and surface bark consumed at lower heights. On fibrous-barked trees, fire will run up the tree to a greater height.
Tree canopy	Leaves consumed or killed	Leaves unaffected, maybe some scorched.

Figure 4.3: *Regeneration of trees after fire*

Some Australian plants are finely adapted to fire conditions. The frequency of fire affects the growth cycle of plants. If fires do not occur for a long period, seed from some species will lie on forest floors unable to germinate. If fires occur too frequently, some plants will not be mature enough to produce and distribute seed. If they are destroyed by fire before producing seed, the area may be taken over by other species better adapted to frequent fires. The vegetation balance would then be altered.

Some species, such as mountain ash (*Eucalyptus regnans*), may not survive if fires are too frequent. The plants may not be old enough to produce sufficient seed before the next fire episode. In this case, mountain ash will be replaced by another species that has adapted to frequent fires, such as messmate (*Eucalyptus obliqua*).

The intensity of a bushfire is measured by the rate of heat (energy) released at the fire front. Intensity depends on the amount of fuel (vegetation) available and how fast the fire travels. Spring and early summer fires burn cooler and are less intense compared to those occurring in mid to late summer and early autumn. The season in which the fires occur has an effect on the impact on vegetation and on seed germination. In some instances, weed species may take over.

The greater the fire intensity the higher the **scorch height,** which is, on average, three times the flame height. Below the scorch height, all plant life is burnt or killed.

Bark has the ability to insulate a tree allowing it to re-sprout if the fire is not too intense. A high intensity fire will aid the development of hollows in eucalypt trees.

Within four years of a fire, the number of limbs and logs on the ground are replaced and an understorey of shrubs may grow as buried seeds begin to germinate resulting in a gradual change in vegetation cover.

Figure 4.4: *Summary of effects of fire on animals*

Animals	Effects of a high intensity fire	Effects of a low intensity fire
Invertebrates	High death rate among litter and trunk species.	Animals that can move further, or fly, may survive and rapidly increase in number. Others may move into the area. Lower death rate as less litter depth is burnt and more areas remain unburnt
Birds	High death rate of both small and large species.	Few deaths.
Mammals	Many deaths and injuries from attempts to outrun the fire, suffocation and running back through low flames onto hot ground.	Few ground or arboreal (tree-dwelling) mammals die. Many seek shelter in burrows, tree hollows, gullies or unburnt areas.

Animals

Fire also plays an important role in maintaining populations of certain animals species. Fire affects the age, structure and composition of vegetation, creating habitats which suit different animal species. For example, the silky mouse only lives in heathland vegetation that is between three and 10 years old, after an area is burnt by fire.

Figure 4.5: *Tree hollows provide shelter for wildlife*

Most animal species are reduced in number during or immediately after a fire. Many individual animals may be killed through burning or suffocation. Others may survive the fire, but die shortly afterwards due to predation by other species or food shortages. However, some animals survive. These animals, like some plants, use a number of survival techniques in their response to fire.

Figure 4.4 shows how animals may be affected by high and low intensity fires.

During a fire event, animals such as birds, kangaroos and wallabies may be able to move out of burning areas to safer refuges. But sometimes these animals may get trapped between spot fires and the high intensity front. Wombats, echidnas, reptiles and amphibians may survive fire by seeking shelter in burrows or logs while a fire passes through an area. Possums and other tree dwelling mammals can move from tree to tree ahead of low intensity fires, or seek safety in the high crowns and hollows of trees. However, these animals may be killed during intense fires.

Figure 4.6: *Remote camera images showing the impact of fire on vegetation*

The RSPCA estimated that over a million animals perished in the Black Saturday bushfires on 7 February 2009. Many more would have survived severe burns and returned to their still smouldering habitat because of territorial instincts (for example kangaroos).

The fires on that day also threatened the habitats of more than 40 species of endangered animals in the bushfire regions.

Many insects and spiders are also killed, especially in high intensity fires that destroy the bark and litter layer in which they live. Flying insects have a higher chance of survival if they can move away from the fire.

The loss of habitat has a major impact on aboreal (tree-dwelling) species. The hollows in tree trunks, that are their main habitat, are either burnt, destroyed or exposed to further decay. Many of these hollows can take over one hundred years to form.

Figure 4.6 is a remarkable series of photographs showing vegetation burning as a fire passes across a remote camera set up as part of a research project in the Big River region.

Soil and water

Bushfires can have several effects on soils, depending on how intense the fire is and how hot the soil becomes. Usually, only the top few centimetres are affected as they are subjected to the highest temperatures.

Low intensity fires can sterilise the soil (cause the death of living organisms within the soil). Higher soil temperatures (greater than 100ºC) may change the amounts and availability of nutrients such as nitrogen and phosphorus. These soil changes, along with ash from the fire, may cause an 'ash-bed effect', increasing the fertility of the soil. However, these nutrients dissolve easily in water, and may be washed away from the site by rain.

Figure 4.7: *Erosion after a bushfire has filled the stream with eroded silt and rocks*

Fire may cause changes in the soil's ability to absorb water. If vegetation is destroyed during a fire, the soil is subject to the action of wind and water, making it very susceptible to **erosion.** Very heavy rainfall immediately after a fire may cause massive erosion or mudslides.

Fire can affect stream water quality and may also influence the amount of water produced by a forest that becomes available to streams. Erosion may cause soil, ash and nutrients to be transported into streams. This increases the sediment load and the **turbidity** (cloudiness) of the water or may even fill the stream channel.

The quantity of water produced by an area that has been burnt may initially increase, as there is little vegetation to trap the rainwater. After a period of time though, the new vegetation uses a large amount of water to grow and therefore can reduce the water available from a **catchment.** A regenerating forest often uses much more water than a mature forest due to the quick growth of new plants. This reduction in groundwater and run-off may decrease the amount of water in streams. The 2003 Alpine fires burnt over 25 per cent of the Murray River's Victorian catchment, which created an estimated reduction in flow of at least a 10 per cent.

Approximately one-third of Melbourne's water supply catchments were affected by the Black Saturday bushfires, however there has been no detectable impact on drinking water quality. The Upper Yarra and Thomson Catchments are the two most important water storages for Melbourne and were largely unaffected. Research shows that if the Thomson Catchment (which supplies up to 60 per cent of Melbourne's water) was to suffer from a major fire, then water yields could be reduced by over 30 per cent for at least 30 years.

How does the environment respond to fire?

Plant adaptations

The persistent recovery of native vegetation after fire is a natural wonder. There are a number of responses that Australian plants have to fire. These are due to adaptations each species has developed. The most obvious affect of a fire on vegetation is that plant cover is lost from an area. Severe fires may remove all vegetation whilst less intense fires may affect some species more than others.

Thick bark protects tree ferns and some species of eucalypt (such as messmates). The bark also protects a eucalypt's **epicormic** buds. These buds will sprout new growth if the tree is damaged or loses many leaves due to intense heat. Epicormic buds are located under a tree's bark, along trunks and branches.

Other species may regrow from root suckers or from seed stored in the soil. Regrowth from root suckers can occur up to several metres away from the trunk of the parent tree and is the main

Figure 4.8: *Epicormic buds on a eucalyptus tree*

Figure 4.9: *Banksia seed case*

mechanism of regeneration for the blackwood wattle.

After a fire there is often more open space and a greater amount of light reaching the ground. Some plants produce flowers and seeds after a fire and take advantage of the increased nutrient and light availability. These plants include grass trees and mountain ash. Mountain ash may release massive amounts of seed after a fire (up to 14 million seeds per hectare). Banksia plants store their seeds until the heat of a fire opens the follicles on its flower spikes or 'cones', allowing the seed to be released. The seed falls onto nutrient-rich, ash-covered ground. If there is enough rain, the seeds germinate and grow in the increased light conditions.

Figure 4.10: *A Pygmy possum caught in the fires is fed with a syringe.*

Fire is a disturbance that can increase weed invasion. Browsing of plants by animals can lead to increased pressure on the survival of native plants.

The mountain ash tree is sensitive to fire. It relies on regular, intense fires to release its seeds, which then thrive in the nutrients from the ash and the increased light. If fire does not occur over the life span of the tree (sometimes over 200 years) the species will die out. However, if fires are too frequent (less than 20 years apart), seedlings may be burnt before forming seed and the species will not survive in these locations.

Animal responses

The rate at which individual animal species respond and return to regenerating bushland is determined by their different requirements for food and cover, their ability to reproduce and by the size of the burnt area. Insect populations recover in stages. Insects that live in the leaf litter and soil usually recover after two to three years. But other insects, such as mites, may take four to five years before populations return to pre-fire levels.

As the bushland continues to re-establish, food sources for animals also improve. Browsing animals, such as wallabies and wombats, may forage on young shoots and seedlings. Possums may feed on new flowers and fruit, but will return permanently only when hollows or nest sites become available.

Food sources for some animals, such as owls, magpies and crows, may increase after fires, as the lack of vegetation cover exposes native mice and lizards. Other birds often reappear in the first few years, attracted by the flowering wattles, and insects feeding on the lush new growth.

The middle layer of vegetation grows quickly in the first few years following the fire. This thick regrowth offers more protection for ground-dwelling animals, such as the antechinus and echidna, reducing the number of their predators.

How do people help restore the environment?

In the years since the Black Saturday bushfires in 2009 many Government agencies have been working to help restore the damaged environment. The Statewide Bushfire Recovery Plan has developed a wide range of projects aimed at helping to restore ecosystems and post-fire threats to plants and animals. These projects include: controlling predators such as foxes, temporarily relocating rare fish species until stream flow improves, or providing nesting boxes to replace lost hollows.

Case Study: Alpine Fires

The Alpine National Park, covering some 646 000 hectares, is the largest national park in Victoria. It was declared a national park in 1982 and is one of eight parks that make up the Australian Alps National Parks. At its closest point, the Alpine National Park is approximately 200 kilometres from Melbourne, however the more remote areas are nearly twice this distance from the city.

Vegetation in the region ranges from sub-alpine snow gum woodland and snow grass plain to tall eucalypt forest. The terrain ranges from 500 to 1500 metres above sea level and is noted for its cliffs and gorges. The higher areas are generally

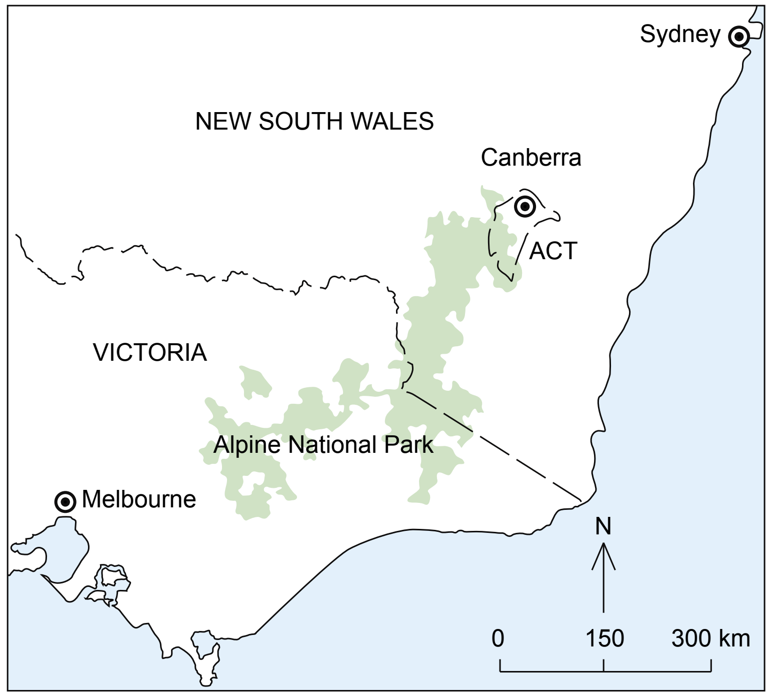

Figure 4.11: *Location of the Alpine National Park in Victoria*

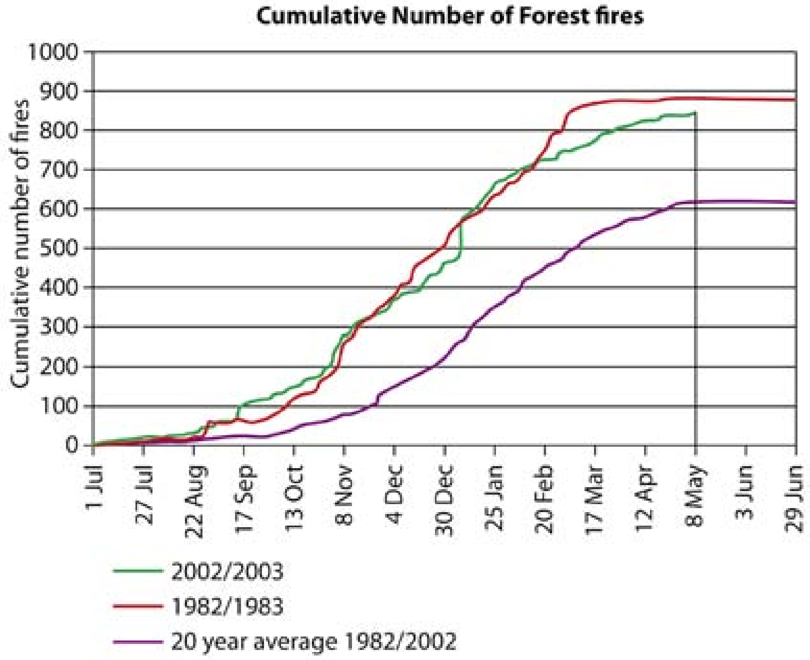

Figure 4.12: *Cumulative number of forest fires*

covered with snow in winter. The area is very popular for fishing, camping and off-road driving

The fires

The fire season for 2002–03 started early, in September 2002. By the beginning of December more than 375 fires had been attended to. This is almost three times the 20 year average.

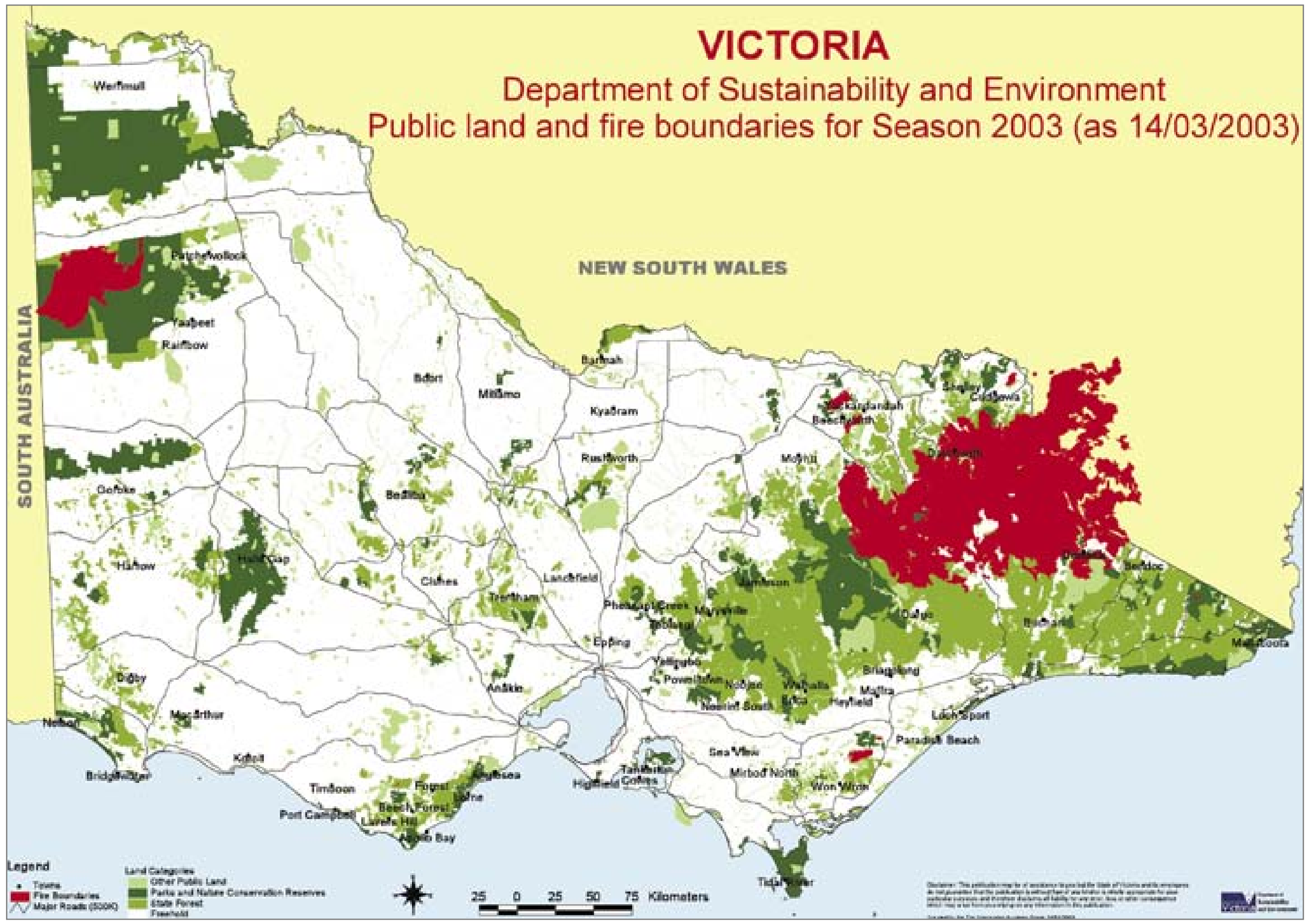

Figure 4.13: *The extent of the Alpine fires*

On 7 and 8 January, 2003, lightning storms swept across much of north-eastern Victoria, igniting more than 80 fires. Most of these were quickly controlled, but the largest fires in the alpine region were in inaccessible regions. Over a period of 59 days the fires in the north and in Gippsland joined with those burning in NSW and the ACT to form a front more than 800 km long. This created one of Victoria's largest bushfires. Figure 4.13 shows the development and extent of the alpine fires.

In all, over 1.9 million hectares of public land and 90 000 hectares of private land were burnt. This represents about five per cent of the area of Victoria. Figure 4.14 compares the size of the fires to the area of Melbourne.

One firefighter lost her life, while on duty, in a flash flood on 26 February. During the fires, 41 dwellings, 213 other buildings and more than 3000 km of fencing was lost. Over 9000 head of commercial stock perished.

Fires in alpine areas tend to be a rare event as the combination of conditions needed—an ignition source, prolonged drought and severe weather conditions—do not often occur. Prior to 2003, the last severe alpine fire occurred in 1939. The large scale of the 2003 fire caused major impacts on the biodiversity of the region, particularly with critically endangered species and habitats.

Whilst vegetation can regenerate, it often takes a long time. It may take decades for some plants to recover in alpine sphagnum bogs compared to three to five years for grassland plants. If the protective layer of vegetation is burnt, the fragile alpine soils are exposed and erosion may occur.

Figure 4.14 *Alpine Fires size compared to the area of Melbourne.*

Figure 4.15: *Long-footed Potoroo*

Fifty-one threatened vertebrate species were found in the area affected by the fires—some of these benefited from the dense regrowth that followed. One such example was the long-footed potoroo whose habitat is dense ground vegetation. Once this was destroyed by fire, the potoroo was vulnerable to predators such as quolls, owls, wild dogs and foxes. However, there was also rapid growth in an underground fruiting fungi that is the staple diet of the potoroo. In the long term, the dense low lying shrub regrowth also provided an improved habitat for the animal.

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Activities

1. What is meant by the term 'fire regime'? How might a change in an environment's fire regime cause changes in the natural environment?

2. Describe the difference in impact of high and low intensity fires on:

a. vegetation

b. animals.

3. Construct a table with two columns to show the direct (short term) impacts of fires on animals and then consider and list the more indirect (long term) impacts.

4. What might happen to some ecosystems if:

a. fires do not occur for a long time

b. fires occur every few years?

5. a. Examine the series of photographs in figure 4.6. Create a timeline to describe the stages of fire progression, temperature readings and the impacts on the vegetation at each stage.

b. What difficulties might the swamp wallaby face at this site on the day after the fire?

6. a. Refer to figure 4.7. Explain what has happened to this stream as a result of fire.

b. Predict what might happen to this stream following heavy rain.

7. Examine the photograph in figure 4.1. How many different impacts of fire can you see in this image? Make a sketch of the photograph and then annotate it with all the possible impacts that may occur at this site.

8. a. Study the graph in figure 4.12. How many fires over a 20 year average occur on 4 March? How many occurred on the same date in 2002–03 bushfire season?

b. Describe, with the use of figures, the general trend in the 20 year average number of fires from July to June.

9. Give reasons to suggest why the Alpine Fires were so difficult to extinguish.

10. Research the habitat and behavior of the pygmy possum and determine how successful this species would be in an alpine bushfire.

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What are the impacts of bushfires on people?

Introduction

European settlers caused great changes to the Australian environment in their attempts to settle and earn a living from the land. In doing so, they altered the relationship between fire and the environment so that, in many places, fire became a threat to people and property.

The regular low intensity fires used by Indigenous Australians were not disruptive to early European settlement. Fire was a useful tool used by Indigenous Australians to clear land and was often left to burn if it got out of control. However, as settlers cleared the land, the vegetation and use of fire changed, creating ideal conditions for more intense fires.

Major Victorian bushfires

Black Thursday, February 1851, provided the first recorded example of a major bushfire in the colony that was to become Victoria. At least 10 lives were lost. On Red Tuesday, February 1898, the death toll was 12 and over 2000 homes, schools, shops and halls were destroyed. The disastrous fires in 1926 claimed 60 lives and 150 homes were destroyed. During January 1939, massive fires raced through large areas of the state causing great loss. Since then Victoria has experienced major bushfires involving large losses of life and property in 1942, 1944, 1952, 1962, 1969, 1977, 1983 and 2009.

Figure 5.1: *The devastating impacts of a major bushfire*

Figure 5.2: *The impact of selected fires in Victoria (continued over page)*

Year	Date	Name/Location	Losses/Summary
2009	February 23	Muskvale / Daylesford, Upwey	3000 hectares
2009	February 13	Wilson's Promontory	5000 hectares
2009	February 7	Black Saturday Churchill, Kilmore and Murrindindi, Vectis (Horsham), Coleraine, Weerite, Redesdale, Harkaway, Upper Ferntree Gully, Maiden Gully / Eaglehawk, Lynbrook / Narre Warren, Beechworth	173 people 2056 houses 239 637 hectares
2009	February 4–6	Bunyip State Park	31 houses 26 200 hectares
2009	January 28	Delburn	44 houses 6534 hectares
2006	December–February 2007	Great Divide Complex	33 houses 13 houses damaged 255 other buildings 1334 animals and livestock Fencing: 1357 km 1 154 828 hectares
2006	January 19	Grampians	2 people 41 houses 9 houses damaged 231 other buildings 65 598 animals and livestock Fencing: 1973 km 116 380 hectares

Year	Date	Name/Location	Losses/Summary
2003	January 8– March 19	North East and Gippsland fires	41 houses 3 bridges 213 other structures 10 000 livestock 1.2 million hectares
2001	December– January 2002	Deployment of CFA to NSW and ACT fires	80 trucks and 2794 CFA personnel were committed for 14 days
1997	January 21	Dandenong Ranges, Creswick, Heathcote, Teddywaddy, Gough's Bay	3 people 41 houses 1 CFA fire truck
1985	January 14	Maryborough, Avoca, Little River	3 people 182 houses 400 farms 46 000 livestock
1983	February 16	Ash Wednesday Monivae, Branxholme, Cockatoo, East Trentham, Mt Macedon, Otways, Warburton, Cudgee, Upper Beaconsfield	47 people More than 27 000 livestock Over 2000 houses/shops
1977	February 12	Penshurst, Tatyoon, Streatham, Creswick, Pura Pura, Werneth, Cressy, Rokewood, Beeac, Mingay, Lismore, Little River	4 people 108 houses/shops More than 236 000 livestock
1969	January 8	Lara, Daylesford, Bulgana, Yea, Darraweit, Kangaroo Flat, Korongvale	22 people 230 houses 21 schools/church/halls More than 12 000 livestock 800 000 acres
1965	February 21– March 13	Gippsland Fires burned for 17 days	More than 60 houses/shops More than 4000 livestock 750 000 acres of forest 40 000 acres of grassland
1965	January 17	Longwood	7 deaths
1962	January 14	The Dandenongs, Christmas Hills, Kinglake, St Andrews, Hurstbridge, Warrandyte, Mitcham	8 people 454 houses
1944	January 14 – February 14	Central & western districts, Morwell, Yallourn	32 people 700 houses Huge livestock losses
1943	December 22	Wangaratta	10 people Thousands of acres of grass country
1939	January 13	Black Friday Rubicon, Woods Point, Warrandyte, Noojee, Omeo, Mansfield, Dromana, Yarra Glen, Warburton, Erica	71 people More than 650 houses/shops
1926	Feb 14	Noojee, Kinglake, Warburton, Erica, Dandenong Ranges	60 people and property
1851	February 6	Black Thursday Wimmera, Portland, Gippsland, Plenty Ranges, Westernport, Dandenong districts, Heidelberg	12 people 1 000 000 plus livestock

Figure 5.3: *Housing on the rural-urban fringe after Black Saturday fires February 2009*

As population has increased in the towns and cities of south-eastern Australia, new suburbs and settlements have developed on the outskirts of cities. This area is known as the rural-urban fringe. Often these settlements are in or near bushland or forests. This trend to semi-rural lifestyles and the ongoing development of the rural-urban fringe means more lives and assets are at risk from bushfires. The value of assets such as houses and buildings has also increased dramatically with rising property values. It is essential that people living in these areas develop an understanding of fire and how to protect themselves and their property.

Why do people die in bushfires?

In a bushfire, people are killed in the following ways: by being directly burnt by flames, by radiant heat, by becoming dehydrated and suffering heatstroke, or by inhaling hot gases from the fire.

If people suffer burns to more than 50 per cent of their body, they are unlikely to survive.

Radiant heat may cause **heatstroke –** this occurs when the body's cooling system fails and, unless treated, will cause death.

Dehydration occurs when a person does not drink enough to replenish water lost from their body. During a bushfire, a person might lose two litres of water per hour. If this is not replaced, the person will become dehydrated and their body will not function properly. Their kidneys and liver may fail and death may occur.

If a person inhales hot smoke, lung tissue may burn and be unable to get sufficient oxygen to the rest of the body.

Many people put themselves at risk during a bushfire because they do not dress correctly. During many bushfire events, people have been observed trying to

Figure 5.4: *Firefighters wearing protective clothing*

defend their homes inadequately dressed in items such as: shorts, singlets, dresses or thongs. Anyone trying to fight a fire should wear protective clothing such as: leather shoes or boots, long trousers (preferably jeans or work trousers), a long-sleeved wool or denim shirt, a hat and something to cover their mouth and nose, such as a scarf or a dishcloth soaked in water.

Driving during a bushfire is very dangerous as cars provide little protection from radiant heat. Conditions can be dangerous, with very poor visibility due to smoke, ember attack or road closures caused by fallen trees. A drive that might normally take minutes may take hours during a fire. However, if you are caught in a car during a bushfire, remaining in the vehicle is safer than trying to escape on foot, unless adequate shelter is nearby. To increase protection from radiant heat:

- park behind a solid structure such as a brick wall or in a clearing well away from debris that might ignite
- close windows and vents, put on hazard lights and headlights, leave the engine running and the air conditioning on re-circulate
- get down as low as possible, below the window height
- cover up with a woollen blanket until the fire front passes
- only get out of the car once the fire has passed.

Why do bushfires burn houses?

It is often noted after a bushfire that one house has burnt while an apparently similar one nearby has survived. Scientists have studied burnt and surviving houses to try and establish the reasons why houses burn. This research has shown that a bushfire can attack a house in three ways: by ember attack, by radiation and by direct flame.

Embers are the main danger to a house. Some embers may start falling up to half an hour before the arrival of a fire front. But the greatest danger of ignition is on the arrival of the fire front and several hours after the front has passed. Many houses have ignited from embers and burnt down long after the fire has passed. Embers can enter a house through unscreened vents, broken windows, gaps in tiles or by melting through skylights. Figure 5.5 shows a build up of leaf litter in a roof gutter which is potential fuel for a fire.

Embers can lodge in gaps such those in window sills. These can build up until even sturdy stumps and poles catch fire. These embers are easy to extinguish if someone is present at the house when the fire arrives and remains long after the fire has passed. The passage of the fire front usually lasts only a short time and, if the surroundings are green and well-maintained, homeowners might go outside and extinguish any small fires that may have started.

Intense **radiant heat** can cause windows to crack and may provide an opening for embers to enter a house. Direct flame may burn a house in situations where garden vegetation or woodheaps are located close by.

Suitable building practices can reduce risk from bushfires. The two most important factors, in regards to house survival, to emerge from the 1983 studies of the Ash Wednesday bushfires were: protection for

Figure 5.5: *Leaf litter in a roof gutter*

windows by shutters or metal fly-wire and the need for people to be present to put out fires caused by embers.

What are the community costs of bushfire?

The whole community suffers as a result of a bushfire. The tragic loss of life and the damage to property can be devastating. Other costs include: injury to people and animals, the loss of production on farms and in factories, and disruption to public services and business. The following are just some of the many examples of the impacts of bushfires on a community.

Impact on infrastructure

Fires can block roads, damage road signs and guard rails. They can also create unstable road embankments due to vegetation loss. The 2003 Alpine fires affected 870 km of roads.

Power poles and transmission lines can also be affected by bushfires. During the 2006–07 Great Divide Fires, smoke from Tatong shorted major high-voltage power

Figure 5.6: *A power pole burning during the Black Saturday bushfires*

lines. This resulted in power loss and a 'brown out' in Melbourne and across much of Victoria. The economic loss from the fire was estimated to be $500 million.

The fires that burnt on Black Saturday, 2009, destroyed many public buildings and businesses such as schools, police stations and shops.

Impact on tourism

The tourism industry, which relies on national parks, alpine areas and some coastal locations, can be badly affected by bushfires. The bushfire in the Grampians in 2006 resulted in an estimated $100 million downturn in the local economy. This was because 60 per cent of the region's businesses derive income from tourism associated with the Grampians National Park. Fires destroyed more than 60 per cent of tourist facilities—such as toilet blocks, camping grounds, information boards and walking tracks—in the 2006 Alpine fires. These facilities take time and money to repair. It is also difficult to attract visitors back to a fire-damaged area for many years.

Impact on agriculture

Fires burning through agricultural land kill stock and burn crops, fences and buildings. It is estimated that stock losses from the 2009 fires were in the order of 11 800 animals. Figure 5.8 shows grapevines destroyed by fire in the Yarra Valley, east of Melbourne during Black Saturday. Grapes that were not destroyed suffered from smoke taint and could not be used. The timber industry is believed to have lost $600 million in burnt timber. (Source: Victorian Bushfires Royal Commission)

Impact on people and communities

Bushfires have both immediate and long-term impacts on people who witnessed the destructive forces of the fire. They may have lost family, friends, pets or homes. The town of Marysville suffered greatly from the Black Saturday fires in 2009, which destroyed much of the township and killed forty people. Being in the media eye can also be distressing and can slow down recovery efforts.

Firefighters, volunteers and emergency service people work under enormous pressures and may suffer emotionally from the fire experience. There can also be stress for survivors dealing with insurance claims, loss of employment and the financial costs of replacing lost property, stock, equipment and fencing.

Figure 5.7: *Tourists facilities, such as this picnic table, can be destroyed in bushfires*

Figure 5.8: *Grapevines burnt in the Black Saturday fires*

Figure 5.9: *The large scale impacts of the Black Saturday bushfire on Marysville*

Figure 5.10: *Unwanted sightseers can be a disruption during times of disaster*

Hundreds of millions of dollars were spent in fire suppression methods during the Black Saturday fires – money was also spent in fire recovery programs. The State Government allocated $40 million into a Royal Commission investigation of the fires. Insurance claims for housing and cars were reported to be $1.2 billion. (Source: Victorian Bushfires Royal Commission)

The myths and realities of bushfires

There are thousands of bushfires in Australia each year. However, very few bushfires actually result in significant losses. In Victoria, only 0.1 per cent of all reported fires—of more than one hectare in size—result in about 85 per cent of total losses caused by bushfire.

By only reporting on major fire events, media accounts are often not representative of the majority of bushfires. Often the most dramatic scenes are shown and reporters may highlight events by using exaggerated language.

Eyewitness accounts are also likely to be affected by the emotional stress of the experience.

A combination of smoke and wind can create darkness, even in the middle of the day. In such darkness, the light of flames can be reflected in the smoke. These billows of red smoke can give the impression that there are rolling balls of fire. Figure 5.11 shows how visibility can be reduced due to smoke.

While bushfires can be extremely dangerous and destructive, there are many misunderstandings about the way bushfires burn. Knowledge of fire behaviour can help distinguish between the reality of fire behaviour and the myths.

Rates of fire spread

On Ash Wednesday, 1983, the rates of spread of some fires were greater than any previously recorded. In some forested areas, fires travelled at 8 km/hr. A fire in the Otways, in open scrub, reached a maximum speed of 18 km/hr. One of the

Figure 5.11: *Visibility can be significantly reduced by smoke, as can be seen in this planned burn*

fastest moving fires ever recorded was 23 km/hr in the Riverina, NSW, in 1987, where not even kangaroos could outrun the flames. The myth that a fire front travels at speeds of up to 100 km/hr, probably resulted from the difficulty of estimating speed due to strong winds and smoke. A fire may seem to advance more quickly because of **fire brands** causing spot fires ahead of the fire front. A steep slope can also have an effect on fire speed. Often the wind causes a 'wave' effect and gives the impression that the flames are travelling very rapidly.

The average grassfire front passes by in a short time as it quickly consumes the available fuel. A forest fire front usually takes longer to pass.

Fireballs

Fireballs are sheets or swirling balls of fire burning in the air. These do not appear to be directly connected to burning fuel on the ground. They are not common and are usually associated with very strong winds. Sometimes pockets of burning gas produced by the combustion of surface fuels can detach and burn quickly. But these cannot roll any distance.

Flame heights can vary from less than 5 metres for a grassfire to several hundred metres for a forest fire. Huge columns of flame are short lived, however and there is no evidence of houses being consumed by a fireball.

Figure 5.12: *Thank you sign*

Fire whirlwinds and tornadoes

Spirals of flame, sometimes called fire whirlwinds or tornadoes, do occur in bushfires. They can vary from a small flame which twists into the air for a few metres, to a giant tornado hundreds of metres high covering several hectares as it moves along. Most fire whirlwinds last for short periods of time and may frequently occur at the bottom of a steep slope under calm wind conditions. Only in extreme bushfires are they significant. Cockatoo, Mount Macedon and the Otways in Victoria—and parts of the Adelaide Hills in South Australia—had very destructive fire tornadoes on Ash Wednesday, 1983.

The 2003 fires in the ACT created a fire whirlwind, which travelled over 14 km with rotational wind speeds estimated at 200 km/hr. This left a trail of damage 200 metres wide.

Cheney Phil & Sullivan Andrew *Grassfires: Fuel, weather and fire behavior*, CSIRO, 2nd Ed

Exploding houses and petrol tanks

Research indicates that houses do not explode spontaneously in the path of a fire. Usually, houses burn from fires started by sparks and embers blown in before the main fire front arrives or after it has passed. Strong winds may cause significant damage to a house, allowing sparks and embers to enter. Whether a house is made of brick or timber is of little significance, since most fires begin in the roof or under the floor.

Despite what is seen in popular movies, it is unlikely that a car will explode in a bushfire. Under extreme temperatures, petrol will vapourise and the mixture will be too rich to explode. The heat of a fire can burn a car, usually starting with the tyres. The grease and oil that builds up around an engine can burn well. If the fire burns the fuel lines then fuel can leak out causing flames to burn under the car.

Fight or flee?

Some people believe that, if necessary, they can leave their home at the last moment. The reality is that they are likely to be safer staying in their homes than fleeing at the last minute by car, or on foot, along smoke affected roads.

In bushfires, flames rarely kill people. They are usually killed by radiant heat. A single bar radiator emits one kilowatt of radiant heat. Radiant heat of 2.2 kilowatts will cause burns to exposed skin. The heat can also cause heatstroke and death because the body's cooling system fails. Radiant heat travels in straight lines and does not penetrate objects. Therefore, sheltering behind a solid structure such as the wall of a house will reduce exposure to radiant heat.

Firefighters will protect my home

There are still people who do little or nothing in the way of fire prevention on their properties. Fires can and do occur just about anywhere. The path of a fire is determined by the location of the ignition point, the direction of the prevailing wind, topography and fuel sources.

Many people believe they can rely on firefighters to protect their home and family during a bushfire. This can sometimes be the case. However, during a major bushfire, firefighters and equipment will be fully occupied controlling the spread of the fire. There will probably not be enough resources to protect every home at risk. People have to take responsibility for their own protection and survival.

Activities

1. How would the threat of bushfires today be different from the times of early European settlers?

2. Look at the data presented in Figure 5.2. How many people lost their lives in these fires? How many homes were lost? What types of infrastructure were destroyed?

3. a. Study figure 5.4. List the different types of protective clothing the firefighters are wearing and state why each piece would be important.

b. Create a poster or collage to show what should, and what should not, be worn during a bushfire.

4. Figure 5.13 shows a house that would be at considerable risk of burning in a bushfire. What suggestions would you make to the owners about how improve their fire safety? Consider using the following subheadings to make a list of suggestions, or redraw the house taking in all your suggestions:

- garden and surrounds
- roof
- walls
- building materials
- other.

Figure 5.13: *A house that would be at risk during a bushfire*

5. How does living on the rural-urban fringe increase the bushfire vulnerability of individuals and communities?

6. Why is it important that people living in these areas learn how to protect themselves and their property?

7. Answer true or false to the following questions:

a. It is easy to estimate the speed of an advancing fire by carefully observing it for a few minutes.

b. Fires travel quicker uphill than downhill.

c. Forest fires take longer to burn through an area than grassfires.

d. A house can explode from a fire even if the windows and doors are locked.

e. More people die from the effects of radiant heat than being directly burnt by flames.

f. When selecting clothing to wear during a bushfire threat, the main aim should be to keep the body cool.

g. A cool change will always reduce bushfire danger.

h. Spot fires do not pose a threat.

Re-write the false statements to make them true.

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How do people respond to bushfire?

Introduction

Humans have become one of the most successful species on the planet because of their ability to adapt to suit different conditions and environments. From the extreme cold of the Arctic Circle to the searing heat of the Australian desert, people have learned how to deal with the natural cycles they are a part of. It is this learning from our environment that is at the core of our success.

The traditional view of bushfires is that they are a natural disaster caused by a set of extreme conditions in the environment. The extent of damage to people and property has been related to the size, frequency and type of fire.

While it would be impossible and undesirable to remove fire from the environment, it is possible for people to influence whether or not they and their property will survive a major bushfire. The magnitude of a bushfire disaster is directly related to the actions and behaviour of people which make them vulnerable in the event of a fire.

The tragedy of the Black Saturday Fires provided us with some valuable lessons on how to plan and prepare for bushfire. After the Bushfires Royal Commission, the idea that bushfire safety is a shared responsibility between people, their community, different agencies (such as Country Fire Authority (CFA) and Department of Sustainability and Environment (DSE)), government, businesses and other organisations was strongly reinforced. This means that everyone must work together to look at ways to minimise the impact of bushfires.

The Victorian Government is responsible for developing laws, regulations and awareness programs that will help people to survive and recover from bushfires. They also partially fund the firefighting agencies that deal with bushfires. All these measures are extremely helpful but bushfire survival ultimately depends on a person's ability to prepare and act. Some of the ways we can help save our property and our lives are shown below. **It is important to visit the CFA website (cfa.vic.gov.au) for the latest safety advice.**

Preparing the home and property for bushfire

Even if you plan to leave early to avoid a bushfire threat you should still prepare your home and property for the coming bushfire.

Vegetation Management (design, choice and control of plants)

One of the most effective ways of decreasing fire threat is to reduce the fuel a fire needs to burn. This can be done by managing the plants, foliage and mulch near your home. If a bushfire occurs, ember attack will still happen but the likelihood of embers starting new fires near your home will be less. It will also reduce radiant heat and direct flame contact that may burn a house.

Some ideas on vegetation management:

- keep grass short—no more than 10 centimetres high
- remove shrubs and woodpiles from near house
- remove weeds and fine fuels—rake up and get rid of branches, twigs and leaves
- make space between plants and trees
- don't use plant-based mulch (i.e. pea straw or woodchips) within 10 metres of your home
- use plants that will not burn readily in a fire
- if you are designing a garden or layout for a rural property use driveways, pools, tennis courts, cultivated soil or gravelled areas, mown lawns, grazed paddocks, dams and natural water features as fire breaks
- keep in mind that older trees can sometimes help shield against radiant heat and embers and can play a useful role in the protection of your home against bushfires.

Managing the vegetation around your home has four main purposes:

1. To give your house the best possible chance of surviving the passage of the fire front.
2. To reduce the chance of direct flame contact and radiant heat igniting your home.
3. To help you protect your home from ember attack.
4. To provide some level of shelter as a last resort if you and your family get caught.

As well as managing the surrounding vegetation, measures to improve the safety of the house itself should be considered.

House improvements

A range of improvements can be made to protect a house during a bushfire. These include:

- protecting underfloor spaces (under verandas or stumped houses) with non flammable sheeting or mesh and clearing out any rubbish
- installing sprinkler systems

- having a firefighting pump and hoses
- making sure gaps, cracks or holes in walls are filled or repaired
- covering external vents with metal mesh (not aluminium)
- placing weather strips on doors and windows to fill gaps
- covering skylights and evaporative coolers with metal mesh

CFA has a free Home Bushfire Advice Service to help you understand the level of risk at your property and what changes can be made to improve your safety (visit: **cfa.vic.gov.au**).

The next link in bushfire survival is preparing yourself.

Developing a Bushfire Survival Plan

In high-risk areas, leaving early is your only safe option on **Code Red** fire danger days.

Leaving early is also your best option on **Extreme** and **Severe** fire danger days. Fires are unpredictable and plans can fail. Having a backup plan can save your life if you are caught in a fire. Know the Fire Danger Ratings at your location. The Fire Danger Rating is your trigger to act. The higher the rating, the more dangerous the situation if a fire starts.

Alert messages and warnings

During a bushfire, alert messages are used to give you an indication of the level of threat from a fire. For alerts and warnings:

- visit cfa.vic.gov.au
- tune in to your emergency broadcasters – ABC local radio, commercial radio and designated community radio stations
- Sky News television
- call the Victorian Bushfire Information Line on 1800 240 667 or via National Relay Service on 1800 555 677
- via the CFA_Updates Twitter account.

For some fires, you may hear the Standard Emergency Warning Signal (SEWS) before the alert message over your radio or television. An Emergency Alert telephone warning may also be sent to your mobile and landline phone. This means if you live in the city and you are travelling in the country when a bushfire happens you will not receive a telephone warning by mobile phone. Do not rely on an official warning to leave. Bushfires can start quickly and threaten homes and lives within minutes. Keep a map of your local area so you can locate and monitor where the fire is. If you are travelling through Victoria, you need to monitor conditions. Reconsider visiting high-risk bushfire areas on fire risk days.

Leave Early

If you live in a high-risk bushfire area, your home will not be defendable on a Code Red day. Even people who are extremely well prepared can die fighting fires at home. The best way to survive a bushfire is to be away from the threat. If you plan to leave then leave early.

Know your trigger to leave

The Fire Danger Rating is your trigger to act. The higher the rating, the more dangerous the situation if a fire starts. On a Code Red day, leaving high risk bushfire areas the night before or early in the morning is the safest option. Don't rely on an official warning to leave. Remember that bushfires can begin and threaten your home and life in a matter of minutes.

Figure 6.1: *Fire Danger Ratings*

Organise where to go

Go to family or friends in a low fire risk area or a place or relative safety, such as a shopping complex or central business district of a large regional or urban centre. Visit other community buildings, such as libraries in low-risk areas. Don't forget to call family, friends and neighbours to let them know where you have relocated. List all the phone numbers you need in your mobile phone. Keep a back-up list written down in case you don't have your phone with you on the day.

Pack a relocation kit as part of your preparations

A bag containing the essentials for life away from home should be packed well ahead of any bushfire threat.

Plan your route

Make preparations and it will be easier to leave early. You will need to know what route to take and decide on another route in case your first choice is blocked or congested. Your normal route may take much longer than expected. If you do not have your own car you will need to think about options, such as public transport or a neighbour. Practise packing the car so it is quick and everything fits—including your pets! It will take a lot longer than you think. Make sure you have enough petrol or fuel so you don't need to stop to fill up.

What to do before you leave

- close all doors and windows
- move doormats and outdoor furniture away from the house
- block the downpipes and partially fill the gutters with water
- move stock or large animals to large paddocks with short grass
- turn off gas supply
- leave the front gate open.

These actions may minimise damage to your home from bushfire.

Know when it's safe to return home

Check with police, fire authorities and your local emergency services before trying to go home. Even if the fire has been controlled, there may be other safety issues that will affect your ability to return home, for example: fallen trees, disruptions to essential services (water, power, telephone), potential crime scenes.

Have a back-up plan if you can't leave

Fires are unpredictable and plans can fail. Having a back-up plan can save your life if you are caught in a fire. If you cannot leave the area, consider shelter options close by. These may include:

- a well-prepared home (yours or a neighbour's) that you can actively defend
- a private bunker (that meets current regulations)
- a designated community shelter or refuge.

Also make sure your plan is flexible to account for different situations such as:

- weekends
- school holidays
- a work day
- when you are away from home.

Help people who need extra support

Do you know family or friends who may need help leaving early on Code Red, Extreme or Severe fire danger days? Red Cross and CFA have produced a booklet to assist people who may need additional support to prepare to leave their homes early on fire risk days.

Community action

Surviving a bushfire is not a matter of luck. Once people understand how fires behave and how they can affect people and their property, it is possible to use simple and inexpensive strategies to improve protection. While there is much individuals can do, often people working in groups are better able to plan and prepare to protect their local community.

In a major bushfire, firefighters will be fully involved trying to control the spread of the fire. It is impossible to have firefighters and equipment on hand to protect every home threatened by a fire. Bushfires are survivable but communities have a responsibility to plan for their own protection.

Community Fireguard is a program to help communities to reduce the loss of lives and property in bushfires. The program is based on small groups of neighbours, working together with the help of CFA. They develop an understanding of fire and choose the best way to protect themselves to suit their local environment, lifestyle, finances and abilities.

The role of firefighting and other agencies

Most fires are controlled before they cause major damage. This emphasises the importance of firefighters stopping a fire before it becomes uncontrollable. However, in bushfires when fire intensities are very high, there is little firefighters can do to halt the spread of the fire. On 7 February 2009, CFA were dispatched to 1386 incidents. Of these, nine could not be suppressed and became significant fires.

In Victoria, there are three firefighting agencies:

- CFA provides fire protection and other emergency services in outer metropolitan Melbourne, provincial cities such as Geelong, all country towns and rural areas.
- The Department of Sustainability and the Environment is responsible for fire prevention and suppression in public land including forest reserves and national parks.
- The Melbourne Metropolitan Fire Brigade is responsible for a large part of the Melbourne Metropolitan Area. Most of its firefighting activities involve residential, commercial and industrial areas.

As well as fighting bushfires, these agencies are also involved in fire prevention activities, land management and assisting communities to be prepared for fire.

Black Saturday 2009 saw the Victorian emergency services work at a level never seen before—CFA was involved not only with the firefighters from the Department of Sustainability and Environment (DSE) but with Victoria Police, Victoria State Emergency Service (VICSES), Department of Human Services (DHS), the Australian Army, Metropolitan Fire and Emergency Services Board (MFB), local councils, welfare organisations and many more. The support of ABC and local radio stations and other media that assisted CFA and the communities on a daily basis was also an integral part of all operations.[1]

Working together

The bushfire strategy for Victoria can be viewed as a massive exercise in teamwork. If the individuals on a team (this means you too!) prepare and act to the best of their abilities then a good outcome can be expected. With the guidance and coaching of the government and the support of agencies and other organisations, the harm caused by bushfires can be reduced. Bushfires are an inevitable part of Victorian summers. It is how we deal with them that will make the difference.

[1] CFA Annual Report 2009

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Putting it all together: Boambilly fires

The following case study is based on a hypothetical fire in a hypothetical location in western Victoria. You will use the information and skills learnt throughout this book and apply them to the fire descriptions provided.

As you follow this fire event you will be asked to construct and label a map overlay to show the movement of the fire. There are also questions to answer—these are highlighted in coloured boxes.

You will need to attach a sheet of tracing paper over the topographic map and then follow the instructions carefully to create an overlay map showing the spread of the fire.

Introduction

Boambilly is located in south-western Victoria. The landscape in the region is flat to undulating, as can be seen in the aerial photograph. The Boambilly River flows through the area and there are a number of shallow swamps which usually fill after long periods of rain. During times of drought, the swamps dry out and are often covered in dry grasses.

HOW TO READ GRID REFERENCES

Topographic (landform) maps have a grid ruled over them, similar to a street directory. Each grid lines has two numbers. First read across the map using the grid lines numbered from west to east (these are called **easting** lines). Then read the **northing** lines (the lines numbered south to north). To find location accurately, further divide each grid square into imaginary 10 grid squares. Picture a place located in area reference (grid square) 6154. If it was located exactly in the centre of the grid, we would say that it is located at 61**5**54**5**, if it was located at the point where easting line 61 meets northing line 54 then the grid reference would be 61**0**54**0.**

The main land use in Boambilly is grazing and grain farming. There is also a pine plantation near Judalong (area reference 7260), with the wood being harvested for the woodchip export industry.

1 Study the topographic map and indentify:

a. The highest elevation (record height and grid reference).

b. Average elevation.

c. Does elevation increase or decrease from west to east across the map?

Weather

The region had been suffering from extreme drought conditions over the past five years with well below average rainfall. January 10 was declared a day of Total Fire Ban, the fifth one in a row. Figures 7.2 and 7.3 show the temperatures, relative humidity and wind speeds for that 24 hour period.

2 Study the climate data. Describe, with the use of figures, the temperature and humidity pattern for the day.

3 Explain how temperatures and humidity influence fire behavior. You may like to refer back to chapter three.

4 A cool change arrived at 1645. What impact did the change have on temperatures, humidity and wind speed?

Figure 7.1: *Aerial view of the region. Boambilly Swamp can be seen in the background filled with water*

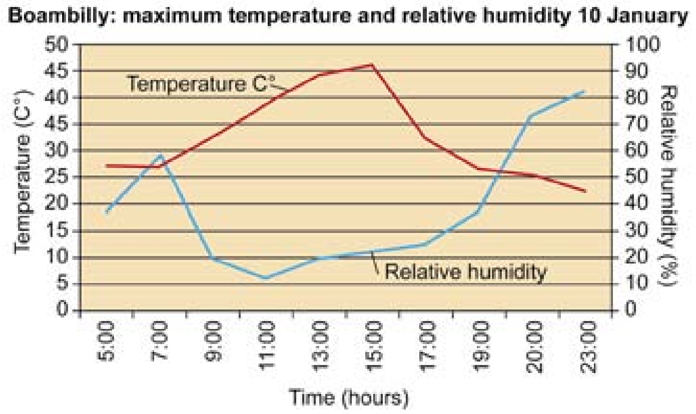


Figure 7.2: *Graph showing temperatures and relative humidity*

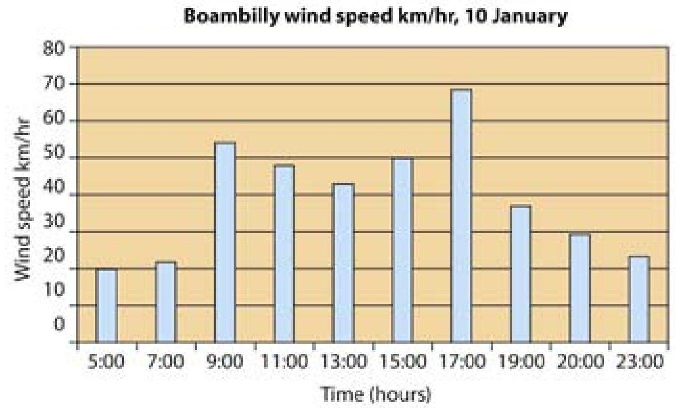


Figure 7.3: *Graph showing wind speed for 10 January*

The fire event

On 10 January a fire was started by lightning at GR 615615 (GR = Grid Reference) at 1350 hours.

Mark this location neatly on your map with red star and record the time. Create a legend to include the symbols you draw.

5 Describe the location of the start of the fire from Boambilly. Use direction and straight line distance in your answer.

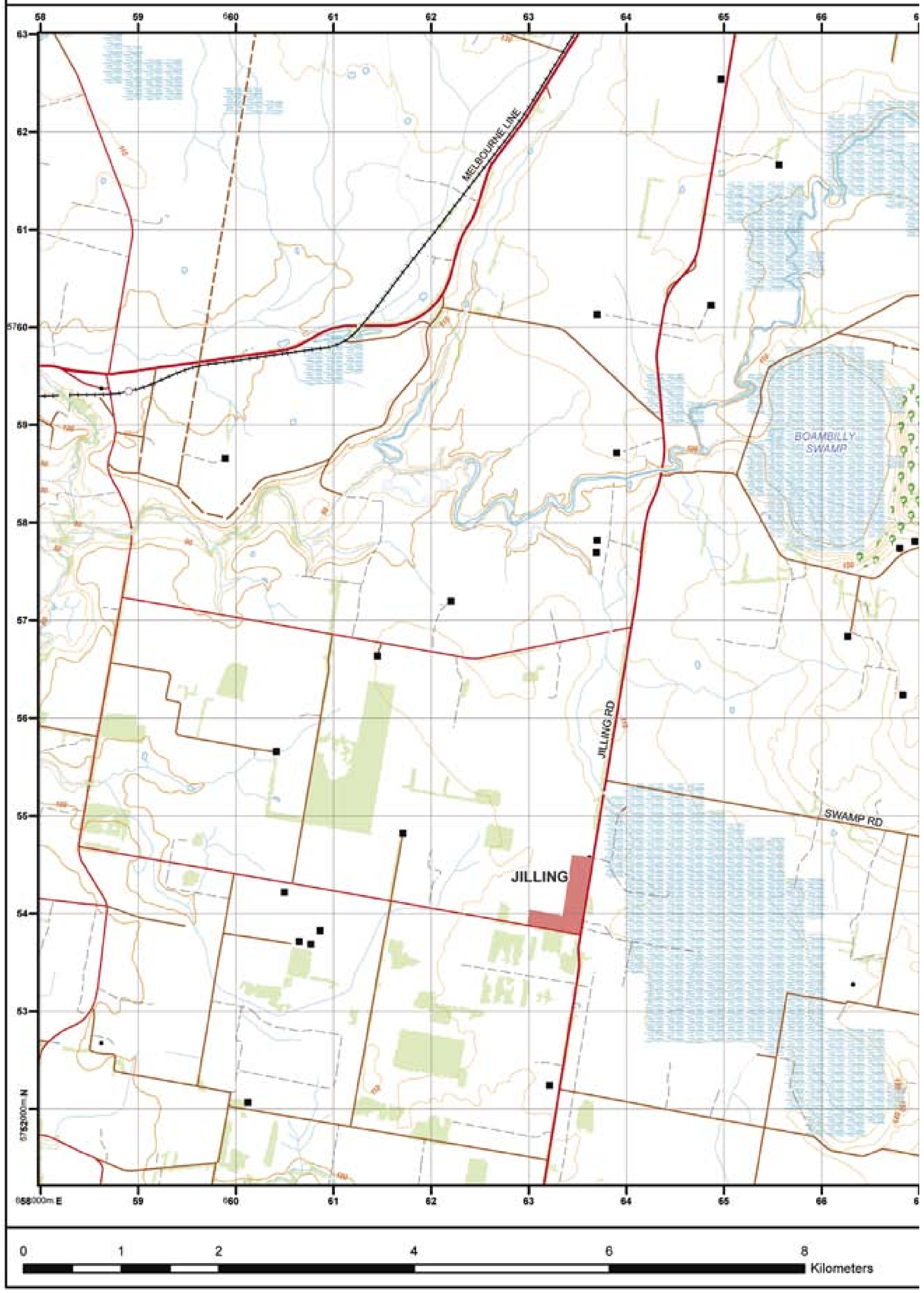
6 Name the first feature threatened by the start of the fire?

7 The nearest CFA station was located at Jilling. Use the correct symbol to label the location of the fire station at GR 636551.

8 Calculate the distance the fire trucks would have travelled by road to reach the start of the fire. How far is the nearest road from the start of the fire?

Fanned by strong north to north-westerly winds, the fire spread quickly through grass paddocks and by 1515, the fire had travelled a distance of 4.5 km with the average width of 1.5 km.

Topographic Map - Boambilly



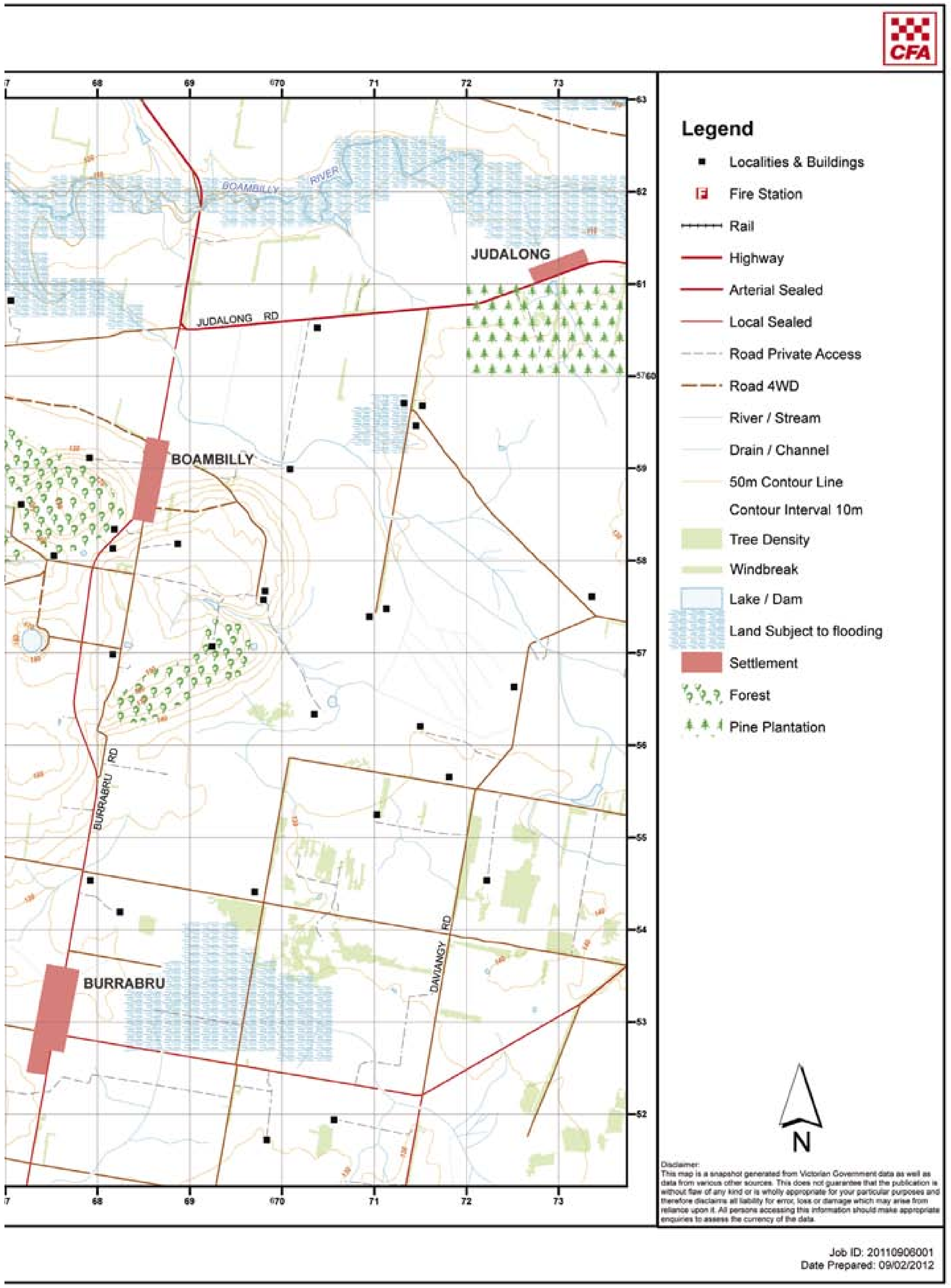


Figure 7.4: *The fire burnt quickly across grasslands*

Figure 7.5: *Mopping up: once a fire has been declared 'under control' there is ongoing work such as extinguishing smouldering logs and breaking up stumps before it is declared 'safe'. This may take several days and sometimes weeks.*

Use a red arrow to show predominant wind direction on your map. Draw a red dotted line with the time attached to show how far the fire has travelled. Refer to figure 3.10 in chapter three to draw the fire shape.

At 1515 firefighters noticed that the rate of fire spread had slowed. However, at 1530, spotting was observed ahead of the fire front at a distance of 1.5 km.

Mark the location of the spotting with a small red dot and include this in your legend. Make note of the time.

9 What natural feature (record the name and grid reference) would have influenced the fire slowing down at 1515?

10 Look closely at the contour lines on the map and suggest a reason for the increase in fire speed at 1530.

By 1600, the spot fire was burning fiercely and accelerating with a front approximately 2 km wide. It had travelled 3 km from the original spot fire, crossing the Boambilly Rd. The original fire front caught up and joined with the spot fire – see figure 7.4.

Mark the spread of the fire on your overlay map and record the new time.

11 a. At 1600, the spot fire had become a fully developed fire and had picked up speed. Was the fire travelling uphill or downhill?

b. Study this area of the map closely and then suggest two reasons why the fire speed increased. Hint: look at figure 3.17 in chapter three.

12 a. Which township was most at risk at this stage?

b. If the fire was travelling at 5 km/hr, how long before it would reach the town?

13 How accessible would this area be for firefighting? Provide evidence for your answer.

14 Give the grid reference for the nearest water source for firefighting. Suggest some of the difficulties the firefighters might have with water sources.

15 Study the photograph, figure 7.5 Which was the most likely location for this photograph to have been taken: GR 667587 or 707587? What evidence did you use in making your decision?

The fire continued to burn and by 1630 was approaching Daviangy Rd.

Mark the spread of the fire on your overlay map.

Burning embers set up two further spot fires started at GR 723583 and GR 734557.

Mark these as spot fires on your map.

16 At 1630 how far apart are the two new spot fires?

17 How many buildings would have been destroyed by this time?

The anticipated cold front moving across the state arrived at 1645, bringing a strong southerly wind change to the fire region. This changed the direction of the fire front. The fire's northern flank became the new fire front and burned in a northerly direction, joining up with the new spot fires.

Mark the change in wind and fire directions on your map.

18 a. What impact would the change in wind direction have on the fire direction and size of the fire front? Refer to figure 3.10 in chapter three to help you.

b. How wide is the fire front on your map after the wind change?

c. Has the fire threat increased or been reduced at this stage? Explain.

19 Use the scale to estimate the total area of the pine plantation that would have burnt.

20 How would a change in vegetation type influence the behavior of a fire? Refer to figure 3.4 to help you.

Heavy rains started to fall at 1900 and the fire was brought under control some hours later as it approached the Boambilly River.

Draw the end of the fire on your map.

Figure 7.6: *Aerial photograph showing the spread of the fire from the point of origin*

Figure 7.7: *The loss of buildings in Boambilly*

Figure 7.8: Fire burning in the Judalong pine plantation

Figure 7.9: Impacts of fire

21 What was the total distance the fire travelled?

22 How would the movement of people and firefighters have been affected by the fire path?

23 Would a fire break, approximately 50 m wide and 1 km long, located parallel with Burrabru Road (from GR 685570 to GR 685560), be effective in stopping the progress of this fire? Give a reason for your answer.

24 Study the photographs Figures 6 to 11. Draw a table to list the impacts of this fire on both people and the environment.

25 Write a concluding paragraph to describe the factors which contributed to the development and spread of the Boambilly bushfire.

Figure 7.10: Impacts of fire

People injured: 6
Area burnt: 29,500 hectares
Houses and other buildings: 27
Cattle/sheep: 1270

Figure 7.11: Table of losses associated with Boambilly fire

Glossary

Aspect The side or surface of a slope or structure facing a certain direction. For instance: a northern or western aspect.

Air mass A large body of air with similar temperature and moisture.

Atmospheric stability The degree to which the atmosphere resists turbulence and vertical movement.

Back-burning A fire started intentionally from a prepared line or other barrier to burn an area of flammable material in the path of an advancing fire.

Burning off Setting fire to an area to burn leaf litter and unwanted vegetation. Often requires regulations to be followed.

BOLTSS Border, Orientation, Legend, Title, Scale, Source.

Bushfire A general term used to describe a fire burning out of control in vegetation.

Catchment The area which is drained by a river and its tributaries.

Combustion The act or process of burning.

Community Fireguard A program to help communities reduce the potential loss of lives and property in bushfires.

Contained A fire is 'contained' when its spread has been halted, but it may still be burning freely within the perimeter. Further work is required to bring the fire to a 'controlled' status.

Convected heat Heat transmitted by hot gases including the combustion products of a fire.

Convection column Thermally-produced vertical columns of ash, smoke and fire debris.

Conduction Transfer of heat through a solid object from a region of higher temperature to a region of lower temperature.

Crown fire A fire that burns into the canopy of trees ahead of fire in the undergrowth.

Curing The progressive drying out of grasses after flowering or during a drought period.

Diurnal range The difference between maximum and minimum temperatures for one day.

Elevation Height above sea level, or altitude.

Erosion The wearing away of the earth's surface by the action of water and wind.

Epicormic buds New growth produced from buds beneath the bark of a tree's trunk or branch.

Extreme fire danger The second-highest fire danger warning provided by the Fire Danger Rating in Victoria.

Fire behaviour The way in which a fire reacts to variables in fuel, weather and topography.

Firebrand Any burning material from one fire that could start another, for example, sparks or embers.

Fire danger rating predicts how a fire would behave if started, including how difficult it would be to put out.

Fine fuels Grass, leaves and twigs less than 6 mm in diameter.

Fire Danger Index (FDI) A numerical value that indicates the potential for a fire to develop and how fast it might travel on a given day.

Fire frequency How often a fire occurs.

Fire intensity A measure of the heat energy released at the fire front.

Fire regime The set of characteristics of an area, related to fire intensity, frequency and season.

Fire season The period of the year during which bushfire is likely to occur, spread and do sufficient damage to warrant organised control.

Fire suppression All work and activities associated with fire fighting.

Forest fire A fire mainly in forest or woodland area.

Fuel Anything which serves to ignite or sustain fire. In relation to scrub and grass, it can be classed as light or heavy. Usually expressed in tonnes per hectare.

Fuel moisture content The water content of a fuel expressed as a fraction of its oven-dried weight.

Fuel reduction burning The application of fire to an area to reduce its fuel load and minimise the negative effect of potential bushfire.

Grassfire A fire predominantly in grass country.

Ground fire A fire burning in thick layers of humus and vegetation, usually in forest, swampy ground or peat. Fires in rubbish dumps may fall into this category, but otherwise ground fires are uncommon in Victoria.

Indraught wind Cooler air moving in to replace rising hot air. This wind creates convection columns.

Lee-side The protected side away from the wind. The opposite of windward.

Litter Top layer of the forest floor composed of leaves, twigs and other plant matter undergoing decomposition.

Mopping up Process of making a fire safer after it has been controlled. For example, removing burning material.

Pyrocumulus clouds Large cumulus clouds which form above a bushfire.

Radiant heat Heat transferred in the form of electromagnetic radiation

Rate of spread How far and fast a fire spreads over a period of time.

Relative humidity The amount of water vapor present in the air expressed as a percentage of the amount that would saturate the air at the same temperature.

Rural-urban fringe an area of gradual change between an urban area and a rural area.

Smouldering Slow burning with smoke but no flame.

Scrub fire A fire burning in an area dominated by shrubs and short trees.

Sparks and embers Small pieces of burning fuel carried by the wind.

Spotting The ignition of spot fires from sparks or embers.

Spot fire Isolated fire started by sparks, embers or other ignited material ahead of the main fire.

Structural fire A fire involving a construction or structure, usually buildings.

Surface fire A fire which burns in the surface fuels of an area. These fuels may be grass, low shrubs, leaves and litter.

Topography The shape and physical features of the Earth's surface including hills, valleys and mountains.

Total Fire Ban A period of time when fires may not be lit in the open.

Turbidity The cloudiness of water due to sediment.

Woodland Plant community typified by scattered trees, open canopy and grasses.

Wildfire Any unplanned rural fire requiring suppression action. (See bushfire)