ABCB

National Construction Code

Handbook

Bushfire Verification Method

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Preface

The Inter-Government Agreement (IGA) that governs the Australian Building Codes Board (ABCB) places a strong emphasis on reducing reliance on regulation, including consideration of non-regulatory alternatives such as non-mandatory handbooks and protocols.

This Handbook is one of a series produced by the ABCB developed in response to comments and concerns expressed by government, industry and the community that relate to the built environment. The topics of Handbooks expand on areas of existing regulation or relate to topics which have, for a variety of reasons, been deemed inappropriate for regulation. They provide non-mandatory advice and guidance.

This Handbook assists in understanding the Bushfire Verification Method in NCC Volumes One and Two. It addresses issues in generic terms, and is not a document that sets out regulatory requirements or detailed technical specifications. It is expected that this Handbook will be used to guide solutions relevant to specific situations in accordance with the generic principles and criteria contained herein.

Contents

REMINDER

This Handbook is not mandatory or regulatory in nature and compliance with it will not necessarily discharge a user's legal obligations. The Handbook should only be read and used subject to, and in conjunction with, the general disclaimer at page i.

The Handbook also needs to be read in conjunction with the relevant legislation of the appropriate State or Territory. It is written in generic terms and it is not intended that the content of the Handbook counteract or conflict with the legislative requirements, any references in legal documents, any handbooks issued by the Administration or any directives by the Appropriate Authority.

1 Background

The NCC is a performance-based code containing all Performance Requirements for the construction of buildings. To comply with the NCC, a solution must achieve compliance with the Governing Requirements and the Performance Requirements. The Governing Requirements contain requirements about how the Performance Requirements must be met. A building, plumbing or drainage solution will comply with the NCC if it satisfies the Performance Requirements, which are the mandatory requirements of the NCC.

1.1 Scope

This Handbook has been developed to provide guidance to practitioners seeking to demonstrate compliance for construction in bushfire prone areas using the Verification Methods GV5 and V2.7.2. It will be of interest to all parties who are involved in selecting or assessing elements of buildings that must comply with the NCC Performance Requirements relevant to construction in bushfire prone areas.

It should be noted that GV5 and V2.7.2 Verification Methods are optional assessment methods that can be used to demonstrate compliance with the NCC Performance Requirements relevant to construction in bushfire prone areas. The use of Deemed-to-Satisfy (DTS) methods (e.g. Australian Standard AS 3959 (Standards Australia 2018[21]) and other assessment methods to determine compliance with the Performance Requirements for construction in bushfire prone areas are also permitted in the NCC (ABCB 2019[4, 5]).

Further reading on this topic can be found with the references in Section 9 of this document.

1.2 Design and approval of Performance Solutions

The design and approval processes for Performance Solutions for construction in bushfire prone areas is expected to be similar to that adopted for demonstrating compliance of other NCC Performance Solutions. Since the design approval process for Performance Solutions varies between the responsible State and Territory governments it is likely to also be the case with construction in bushfire prone areas and requirements should be checked for the relevant jurisdiction.

Verification Methods GV5 and V2.7.2 provide quantification of the Performance Requirements for construction in bushfire prone areas. They represent the next logical step in the development of the NCC to fully realise the benefits of performance-based design and facilitate the further development of the NCC to manage bushfire risks in a safe and efficient manner.

Notwithstanding the quantified input and acceptance criteria, other qualitative aspects of Performance Solutions for construction in bushfire prone areas, which are discussed in this document, require assessment and analysis throughout the design and approval process. The advice of an appropriately qualified person should be sought to undertake this assessment and analysis where required, and may be aided by the early and significant involvement from regulatory authorities, peer reviewer(s) and / or a technical panel as appropriate to the State or Territory jurisdictions.

1.3 Using this document

General information about complying with the NCC and responsibilities for building and plumbing regulation are provided in Appendix A of this document. Acronyms used in this document are provided in Appendix B.

Italicised terms are defined terms used in this document. They may align with a defined term in the NCC or be defined for the purpose of this document. See Appendix C for further information.

Referenced documents are located in Section 9. Where a document is referenced, it is identified by a number in superscript (e.g. in the NCC (ABCB 2019[4, 5])).

Different styles are used in this document. Examples of these styles are provided below:

NCC Extracts
Examples
Alerts
Reminders

1.4 Data limitations

In some cases, the supporting data necessary to undertake the complex type analysis may not be available. Through time it is envisaged that data sheets addressing these limitations will be developed in collaboration with fire agencies and industry, and be made publicly available.

1.5 Other ABCB documents

Class 10c buildings (Private Bushfire Shelters) are required to comply with Performance Requirement P2.7.5 which lies outside the scope of Verification Methods GV5 and V2.7.2.

Although some content from this document may be relevant, specific guidance with respect to Class 10c buildings is provided in the document “Performance Standard: The Design and Construction of Private Bushfire Shelters” (ABCB 2014[1]).

2 Introduction to GV5 and V2.7.2 - Verification Methods for building in bushfire prone areas

2.1 Verification Method GV5

Verification Method GV5 is reproduced below:

GV5 Buildings in bushfire prone areas

(a) Compliance with *Performance Requirement* GP5.1 is verified if the ignition probability for a building exposed to a design bushfire does not exceed 10%.

(b) Bushfire design actions must be determined in consideration of the annual probability of a design bushfire derived from—

  (i) assigning the building or structure with an importance level in accordance with GV5(c); and

  (ii) determining the corresponding annual probability of exceedance in accordance with Table GV5.1.

(c) A building or structure's importance level must be identified as one of the following:

  (i) Importance level 1 — where the building or structure presents a low degree of hazard to life and *other property* in the case of failure.

  (ii) Importance level 2 — where the building or structure is not of importance level 1, 3 or 4 and is a Class 2 building accommodating 12 people or less.

  (iii) Importance level 3 — where the building is designed to contain a large number of people and is a—

    (A) Class 2 building accommodating more than 12 people; or

    (B) Class 3 boarding house, guest house, hostel, lodging house or backpackers accommodation; or

    (C) Class 3 residential part of a hotel or motel; or

(D) Class 3 residential part of a *school*.

(iv) Importance level 4 — where the building or structure is—

(E) essential to emergency management or post-disaster recovery; or

(F) associated with hazardous facilities; or

(G) subject to a necessary 'defend in place' strategy and is a—

(aa) Class 3 accommodation building for the aged, children or people with disabilities; or

(bb) Class 3 residential part of a health-care building which accommodates members of staff; or

(cc) Class 3 residential part of a *detention centre*; or

(dd) Class 9a or 9c building; or

(ee) building that operates in the event of a bushfire emergency, such as a public bushfire shelter or a bushfire emergency control centre.

Table GV5.1 Annual Probability of Exceedance (APE) for design bushfire actions

Importance level	Complex analysis APE for bushfire exposure	Simple analysis APE for weather conditions (design bushfire)
1	No requirement	No requirement
2	1:500	1:50
3	1:1000	1:100
4	1:2000	1:200

Note to Table GV5.1: Complex analysis must consider the probability of ignition, fire spread to the urban interface and penetration of the urban interface coincident with fire weather conditions.

(d) The ignition probability for a building must be assessed by application of the following:

(i) An event tree analysis of relevant bushfire scenarios.

(ii) Design bushfire conditions that include combinations of the following actions appropriate to the distance between the building and the bushfire hazard:

(A) Direct attack from airborne burning embers.

(B) Burning debris and accumulated embers adjacent to a building element.

(C) Radiant heat from a bushfire front.

(D) Direct flame attack from a bushfire front.

(e) Applied fire actions must allow for reasonable variations in—

(i) fire weather; and

(ii) vegetation, including fuel load, burning behaviour of vegetation (including the potential for crown fires); and

(iii) the distance of the building from vegetation; and

(iv) topography, including slopes and features that may shield; and

(v) ignition of adjacent buildings, building elements, plants, mulch and other materials; and

(vi) effective size of fire front; and

(vii) duration of exposure; and

(viii) flame height; and

(ix) flame tilt; and

(x) flame adhesion to sloping land; and

(xi) the height of the building and its elements.

(f) The assessment process must include consideration of—

(i) the probability of non-complying construction of critical aspects of an approved design; and

(ii) the probability of critical aspects of an approved design being fully functional during the life of the building; and

(iii) inclusion of safety factors; and

(iv) sensitivity analysis of critical aspects of a proposed design.

2.2 Verification Method V2.7.2

Verification Method V2.7.2 is reproduced below:

V2.7.2 Buildings in bushfire prone areas

(a) Compliance with P2.7.5 is verified if the ignition probability for a building exposed to a design bushfire does not exceed 10%.

(b) Bushfire design actions must be determined in consideration of the annual probability of a design bushfire derived from—

(i) assigning the building or structure with an importance level in accordance with (c); and

(ii) determining the corresponding annual probability of exceedance in accordance with Table V2.7.2.

(c) A building or structure's importance level must be identified as one of the following:

(i) Importance level 1 — where the building or structure presents a low degree of hazard to life and *other property* in the case of failure.

(ii) Importance level 2 — where the building or structure is not of importance level 1 or 4 and is a Class 1a or 1b building accommodating 12 people or less.

(iii) Importance level 4 – Where the building is a Class 10c building and is subject to anecessary 'defend in place' strategy.

Table V2.7.2 Annual Probability of Exceedance (APE) for design bushfire actions

Importance level	Complex analysis APE for bushfire exposure	Simple analysis APE for weather conditions (design bushfire)
1	No requirement	No requirement
2	1:500	1:50
3	N/A for Class 1 and 10 buildings	N/A for Class 1 and 10 buildings
4	1:2000	1:200

Note to Table V2.7.2: Complex analysis must consider the probability of ignition, fire spread to the urban interface and penetration of the urban interface coincident with fire weather conditions.

Explanatory information:

Volume Two does not apply to buildings that are importance level 3, therefore this importance level is not included under (c).

(d) The ignition probability for a building must be assessed by application of the following:

- (i) An event tree analysis of relevant bushfire scenarios.
- (ii) Design bushfire conditions that include combinations of the following actions appropriate to the distance between the building and the bushfire hazard:
  - (E) Direct attack from airborne burning embers.
  - (F) Burning debris and accumulated embers adjacent to a building element.
  - (G) Radiant heat from a bushfire front.
  - (H) Direct flame attack from a bushfire front.

(e) Applied fire actions must allow for reasonable variations in—

- (i) fire weather; and
- (ii) vegetation, including fuel load, burning behaviour of vegetation (including the potential for crown fires); and
- (iii) the distance of the building from vegetation; and
- (iv) topography, including slopes and features that may shield; and
- (v) ignition of adjacent buildings, building elements, plants, mulch and other materials; and
- (vi) effective size of fire front; and
- (vii) duration of exposure; and
- (viii) flame height; and
- (ix) flame tilt; and
- (x) flame adhesion to sloping land; and
- (xi) the height of the building and its elements.

(f) The assessment process must include consideration of—

(i) the probability of non-complying construction of critical aspects of an approved design; and
(ii) the probability of critical aspects of an approved design being fully functional during the life of the building; and
(iii) inclusion of safety factors; and
(iv) sensitivity analysis of critical aspects of a proposed design.

2.3 Ignition and fire initiation

Ignition for the purpose of GV5 and V2.7.2 is considered as fire initiation (within the building) rather than ignition (of the building). This is to clarify that ignition of the external facade of a building is permitted provided the fire does not spread to the inside of the building, but burns out or self-extinguishes.

This is consistent with the NCC DTS requirements provided in AS 3959 Construction of Buildings in Bushfire-Prone Areas (Standards Australia 2018[21]) and the following referenced test standards for evaluation of the performance of elements of construction:

> AS 1530.8.1-2007 Methods for fire tests on building materials, components and structures - Tests on elements of construction for buildings exposed to simulated bushfire attack - Radiant heat and small flaming sources (Standards Australia 2007[19]).
>
> AS 1530.8.2-2007 Methods for fire tests on building materials, components and structures - Part 8.2: Tests on elements of construction for buildings exposed to simulated bushfire attack—Large flaming sources (Standards Australia 2007[20]).

2.4 Application of GV5

Verification Method GV5 can be used to demonstrate compliance with the following Performance Requirement:

- NCC Volume One Performance Requirement GP5.1 (ABCB 2019[4])

2.5 Application of V2.7.2

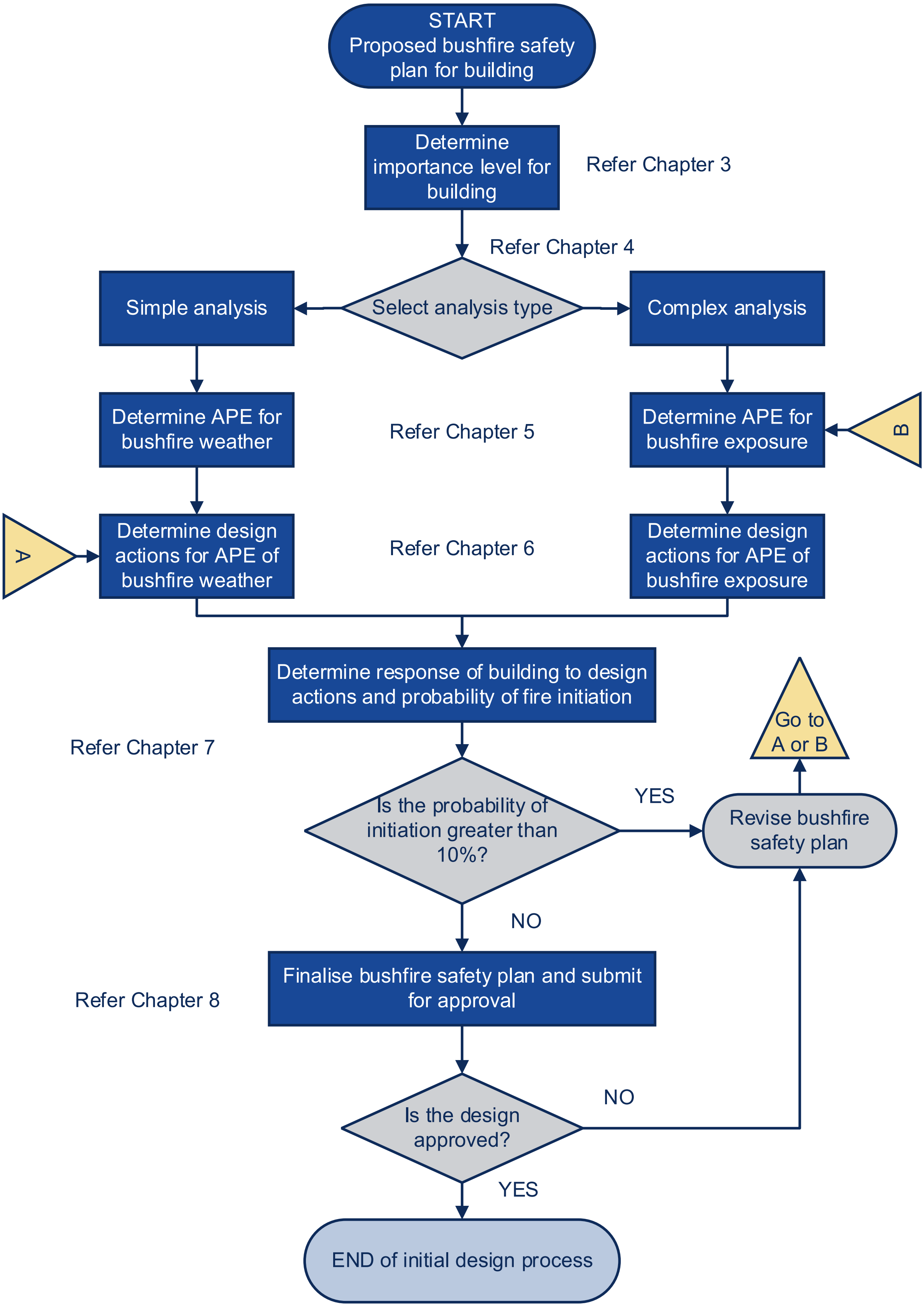
Verification Method V2.7.2 can be used to demonstrate compliance with the following Performance Requirement:

- NCC Volume Two Performance Requirement P2.7.5 (ABCB 2019[5]).

2.6 GV5 and V2.7.2 Procedures

The flowchart at Figure 2.1 shows the processes to be followed when using Verification Methods GV5 or V2.7.2

Figure 2.1 Verification Methods GV5 and V2.7.2 flowchart



The process for determining the importance level of a building or structure is described in Chapter 3.

The process for the selection of the type of analysis is described in Chapter 4. There are two types of analysis defined in GV5 and V2.7.2:

(i) A **simple method** that can be applied to a particular site based on the vegetation and topography surrounding the building with the APE expressed in terms of fire weather (weather conditions).

(ii) A **complex method** that considers the probability of a building being exposed to bushfire attack with the APE expressed in terms of exposure to bushfire attack. This requires consideration of the frequency of ignitions and probability of fire spread from the surrounding areas. In some instances, adequate data may be unavailable and / or for smaller buildings the resources required to undertake the complex analysis may be unable to be justified.

Chapter 5 describes the process for determining the prescribed APE.

Chapter 6 describes options for the determination of design actions.

Chapter 7 describes options for the determination of the response of elements of construction to bushfire attack and the probability of fire initiation.

Chapter 8 relates primarily to implementation and maintenance of provisions but includes information relating to the development of a bushfire safety plan.

3 Determination of importance level of building

Buildings are assigned importance levels based on the following parameters:

- the role they play during a fire emergency and subsequent recovery period
- hazard to life and other property in the case of failure
- number of occupants
- practicality of and safety during evacuation
- proximity to buildings of higher importance levels:
  - importance level 1 is the lowest importance and no protection is required.
  - importance level 4 requires the highest levels of protection.
- assignment of importance levels to buildings are provided in GV5 and V2.7.2.

4 Selection and analysis type

4.1 Introduction

The selection of the analysis type, either simple or complex, depends on the specific building solution under consideration, available resources and data, and the benefits likely to be attained versus additional cost of analysis if the complex analysis is adopted rather than the simple analysis.

In some cases, the supporting data necessary to undertake the complex type analysis may not be available. Through time it is envisaged that data sheets addressing these limitations will be developed in collaboration with fire agencies and industry and be made publicly available.

This chapter provides information to assist designers to select the most appropriate analysis type for a specific project.

The complex analysis facilitates the consideration of a holistic approach to bushfire safety by taking into account fire prevention strategies and management of bushfires before they interact with the built environment. Thus the complex analysis requires consideration of the frequency of ignition; fire spread to the urban interface and penetration of the urban interface coincident with severe fire conditions; and the impact of local topography and vegetation, when estimating design actions. Typically for the complex analysis, all branches of the fire safety concepts tree described in Section 4.4 should be considered.

The simple analysis only requires buildings to be designed based on the annual probability of exceedance of fire weather (weather conditions) and local topography and vegetation (i.e. the design assumes that the building is exposed to bushfire attack coincident with the appropriate APE for weather conditions). Therefore, the Prevent Ignition and most of the Manage Fire branches of the fire safety concepts tree described in Section 4.4 are not applicable, reducing the level of analysis and need for data significantly.

Alert

In geographic areas where historic losses are low, the greatest advantage can be expected from the complex type of analysis since it considers the probability of exposure of the building to bushfire attack, whereas the simple method assumes bushfire exposure occurs coincident with the APE for fire weather.

However, in some cases, the supporting data necessary to undertake the complex type analysis may not be available and / or the additional cost of the complex analysis may not be justified having regard to the size of project.

These issues need to be considered when selecting the type of analysis to be undertaken.

A.1 Fire losses by State and Territory

Historic bushfire losses in terms of civilian fatalities and house equivalents by State and Territory are shown in Figure 4.1 and Figure 4.2 respectively, clearly demonstrating a heavy bias towards Victoria and to a lesser extent NSW. The house loss equivalent includes an adjustment for changes in population / number of houses over the sample period.

These distributions highlight the potential advantages in adopting the complex method to address the lower bushfire risks in many parts of Australia instead of the simple method, which specifies APEs based on weather conditions.

Figure 4.1 Total civilian fatality distribution derived from Blanchi (2012[7])

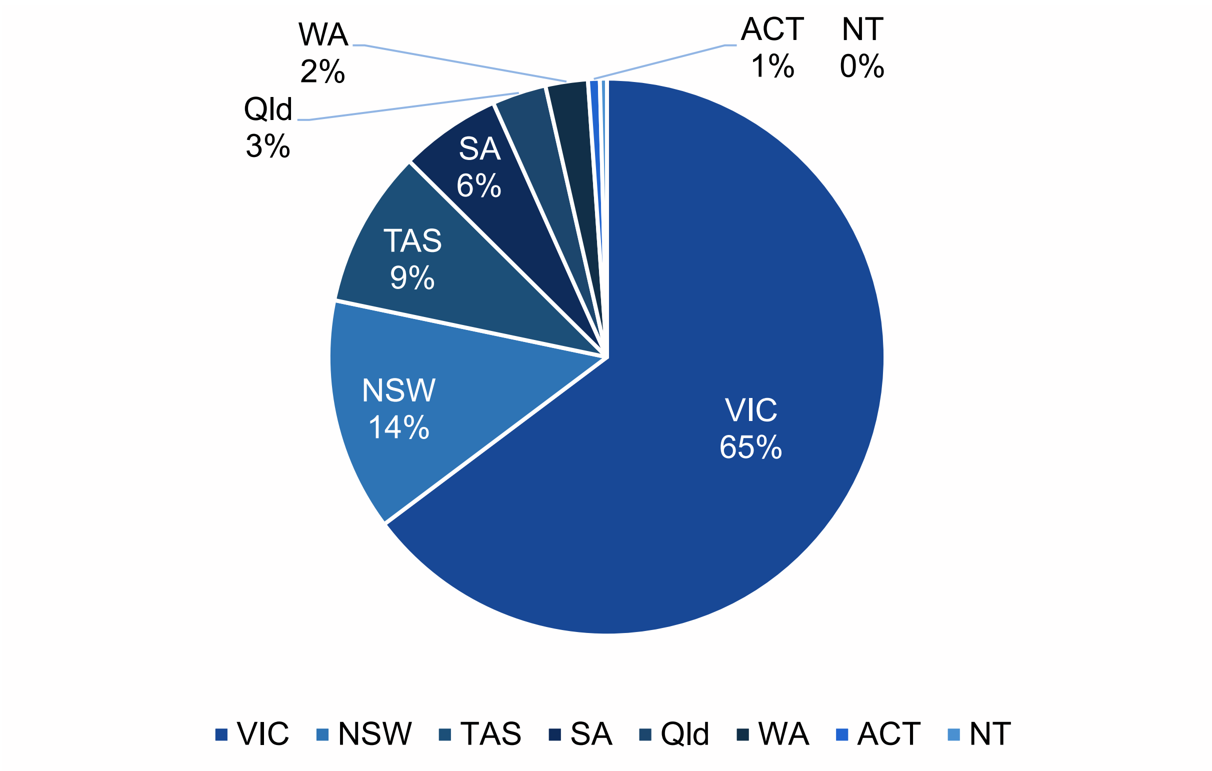
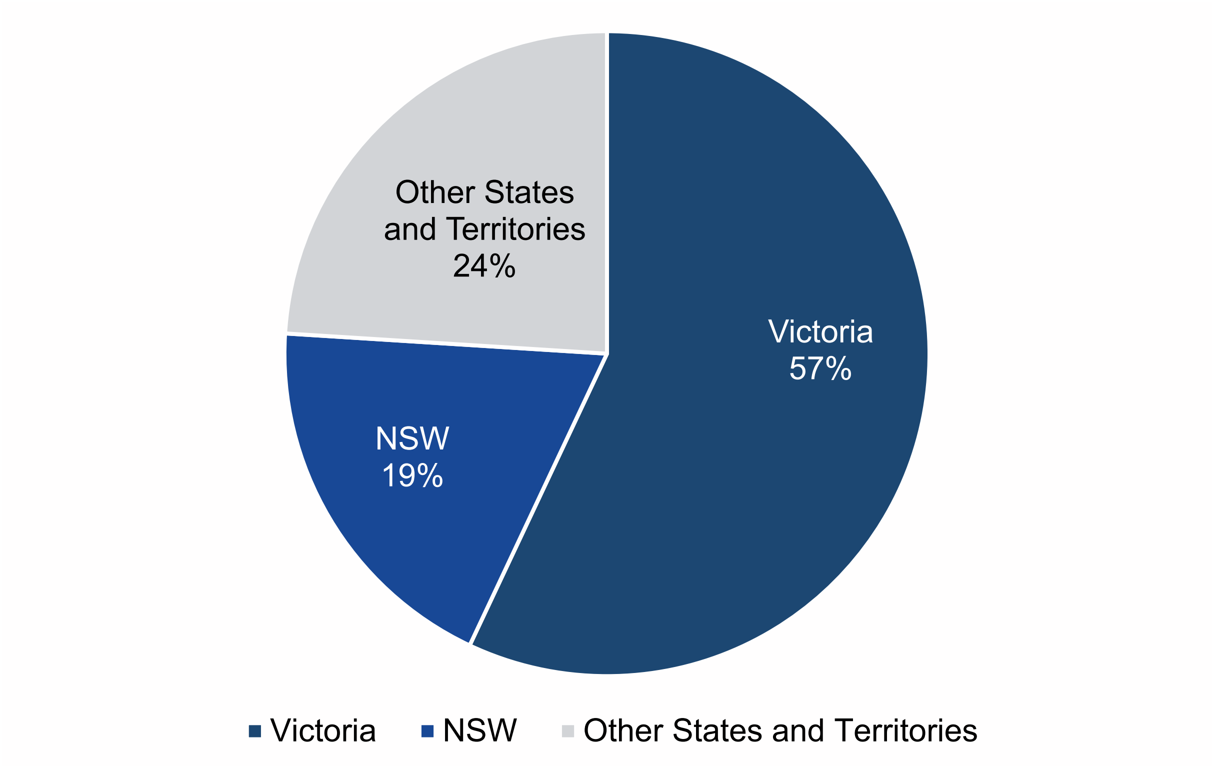


Figure 4.2 Total house loss equivalent derived from Blanchi (2012[7])



4.2 Proportion of losses from single fires

Table 4.1 is a summary of major bushfire incidents from the life and house loss database reported by Blanchi (2012[7]). The database does not capture all bushfire loss data but does provide a reasonable sample covering 733 civilian fatalities. Fires such as Black Friday, Black Saturday and Ash Wednesday, whilst grouped as single events, resulted from a number of separate fires that occurred at the same or similar time within a region exposed to extreme weather conditions.

Table 4.1 Major fire loss consolidated events derived from Blanchi (2012[7])

Dates of Fire	Description	State	Civilian Fatalities	House Losses
14 February 1926	Black Sunday Gippsland	VIC	31	550
10-13 January 1939	Black Friday	VIC	66	650
14 January 1944 & 14 February 1944	Linton & Morwell	VIC	48	700
7 February 1967	Black Tuesday Hobart	TAS	64	1257
8 January 1969	Lara	VIC	20	230
16 February 1983	Ash Wednesday VIC	VIC	46	2060
16 February 1983	Ash Wednesday SA	SA	27	383
7 February 2009	Black Saturday	VIC	172	2021
	Total		474	7851

Note: A large proportion of losses in the Lara fire occurred within vehicles in a single incident.

Some key observations from the table are that fatalities varied from 20 to 172 per consolidated incident without adjustment for population over time.

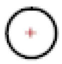
The fires listed in Table 4.1 accounted for 65% of the fatalities recorded in the database. The fatalities occurring in Victoria from seven of these events accounted for approximately 52% of the losses.

4.3 Bushfire risk management and the role of bushfire resistant construction

The fire safety concepts tree defined in NFPA 550 (2012[13]) is a simple qualitative representation of fire safety concepts showing the relationships between fire prevention and various mitigation strategies. It has been adapted for application to bushfires to provide a context for the NCC bushfire Performance Requirements and Verification Methods GV5 and V2.7.2. It shows the interaction with other regulatory and voluntary measures that also impact on the safety of people and buildings and will help to determine the appropriate bushfire safety designs, the type of analysis for a particular application and data requirements.

The concepts tree uses two types of logic gates as shown in Table 4.2 below.

Table 4.2 Types of logic gates

Symbol	Name	Explanation
	OR	The “or” gate indicates that any of the concepts directly below it will cause or have as an outcome the concept above it.
	AND	The “and” gate indicates that all of the concepts directly below it will cause or have as an outcome the concept above it.

The upper levels of the fire safety concepts tree are shown in Figure 4.3 together with mitigation methods relevant to this discussion. Figure 4.4 to Figure 4.7 show the lower branches of the tree and provide further detail.

A review of the lower branches shows interrelationships between many mitigation strategies. No single measure can fully address the bushfire risk and the effectiveness of many mitigation measures is significantly limited by practical considerations (e.g. limited capacity to control or suppress large and severe bushfires, managing other risks such as landslip, human involvement and conflicts with other legislation and social values such as conservation).

The comments below the branches in Figure 4.3 highlight some of the most effective mitigation measures and also show where bushfire resistant buildings and structures fit into the tree (highlighted in the yellow box). In subsequent figures, mitigation measures relating to buildings are also highlighted in yellow boxes.

A large proportion of bushfires are started as a result of human activities. Therefore strategies that can prevent ignition in the first place will provide the best outcomes. However, there will always be a residual risk of natural fire starts (lightning) and it is not possible to totally eradicate fire starts from human activities.

Early suppression of fires before they can take hold minimises damage, but it is reliant upon an “and” gate with five inputs. In addition, the effectiveness of a response is very time sensitive.

The complex method can take these matters into account when determining the frequency of bushfire attack on a specific building or development.

Buildings / structures can contribute to defend in place strategies but are reliant upon “and” gates, with a significant reliance on human activities as shown in Figure 4.7.

Figure 4.8 shows the “accomplish by administrative action branch” with notes showing its application to the design and construction of buildings. It can be observed that in order to achieve the intended outcome there are many administrative processes that must be undertaken. These lie outside the scope of the NCC, which provides technical standards relating to design only, however, administrative processes will impact on the effectiveness of the design features providing resistance to bushfire attack.

Figure 4.3 Upper branches of fire safety concepts tree identifying mitigation measures relevant to analysis

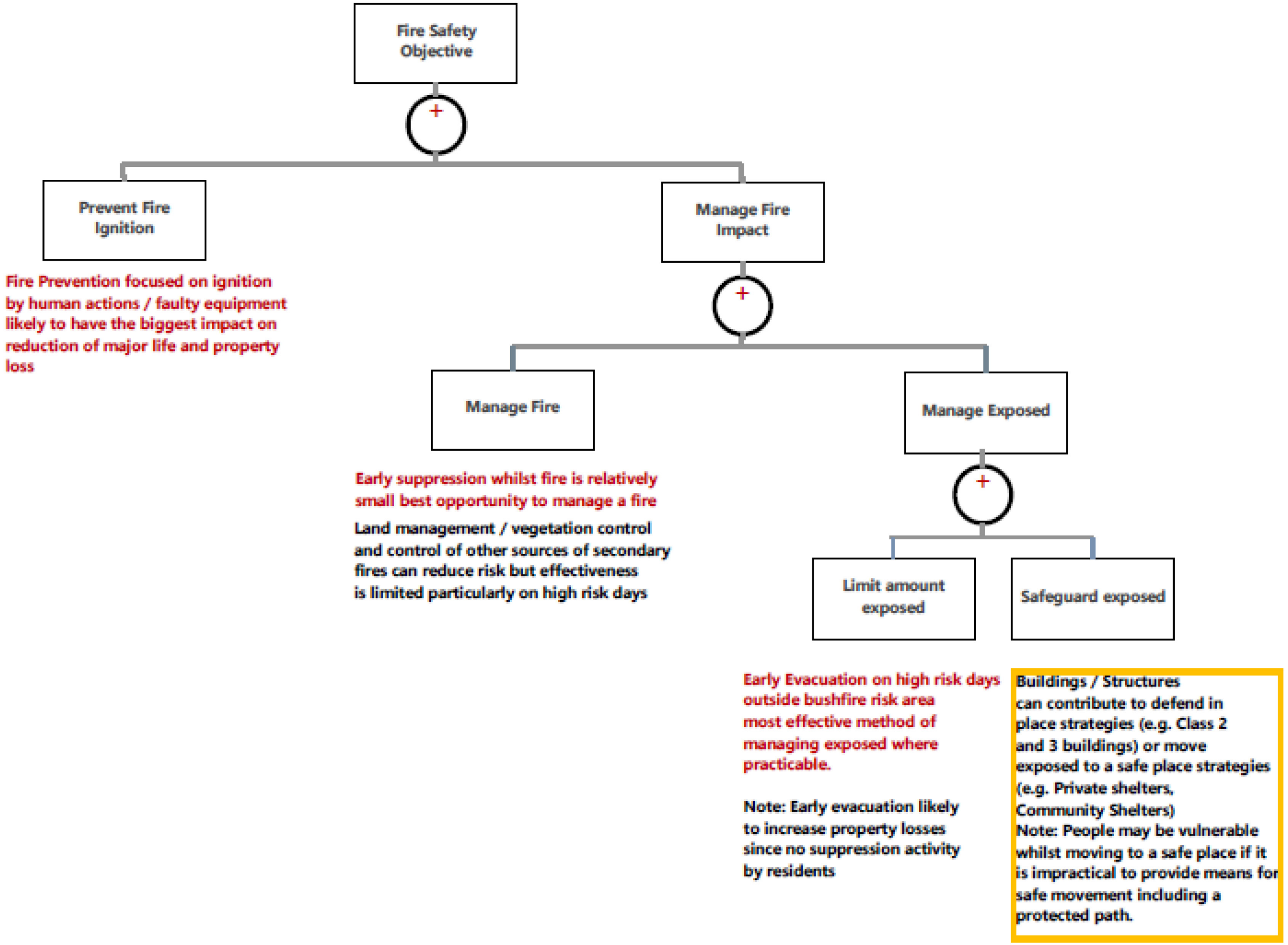


Figure 4.4 Ignition branch of the fire safety concepts tree applied to initial cause of a fire

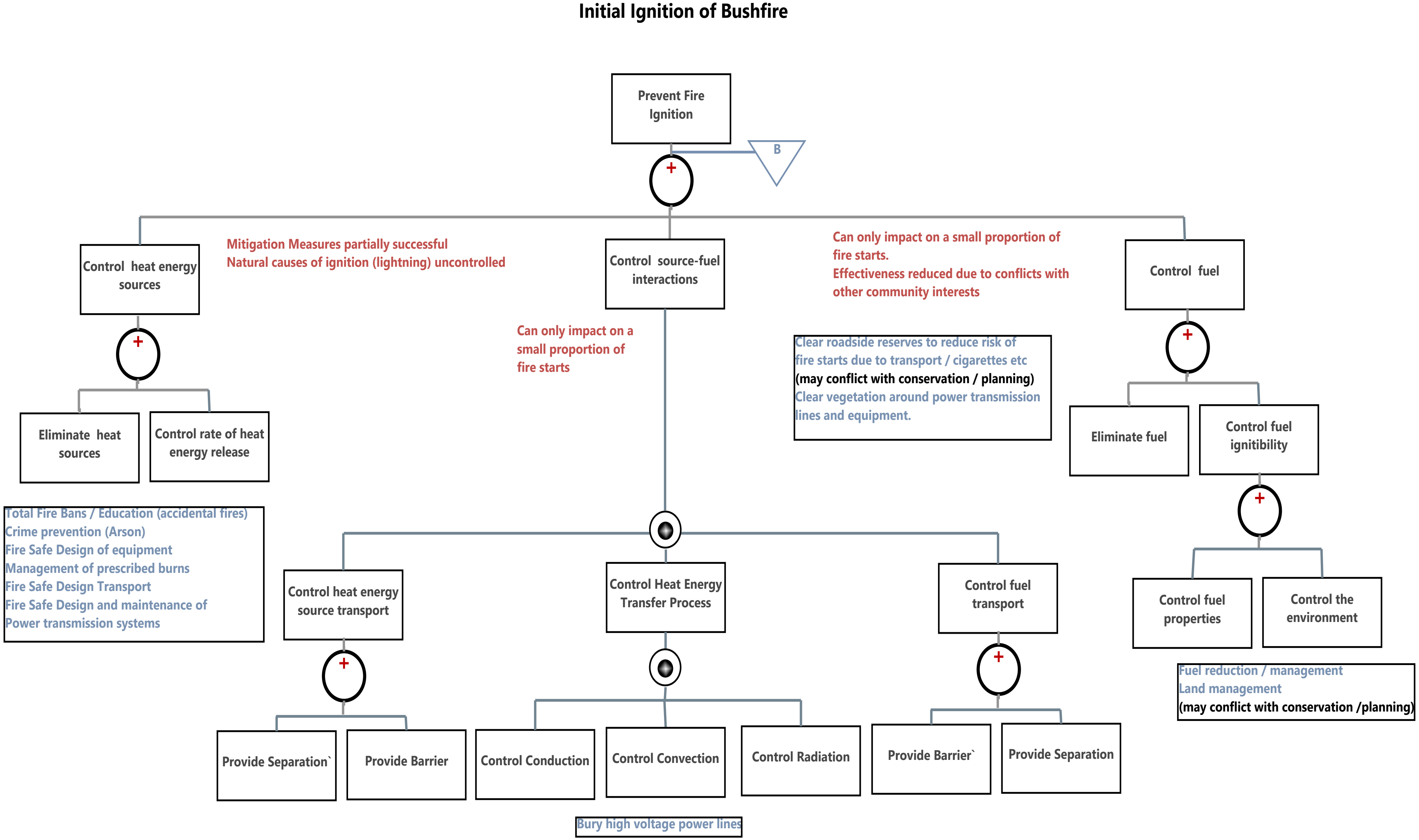


Figure 4.5 Manage fire branch of fire safety concepts tree

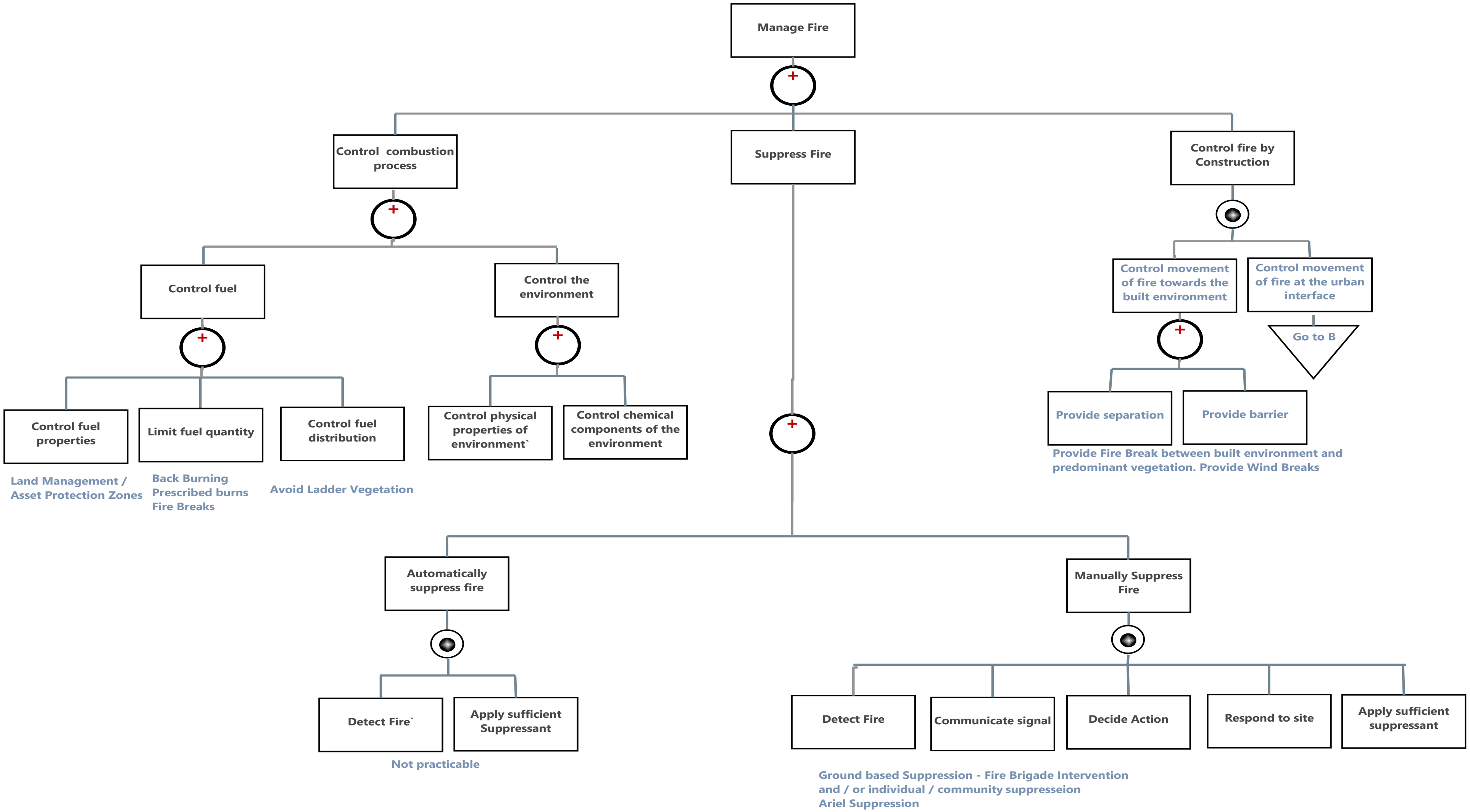


Figure 4.6 Control movement of fire at urban interface sub-branch of control fire by construction

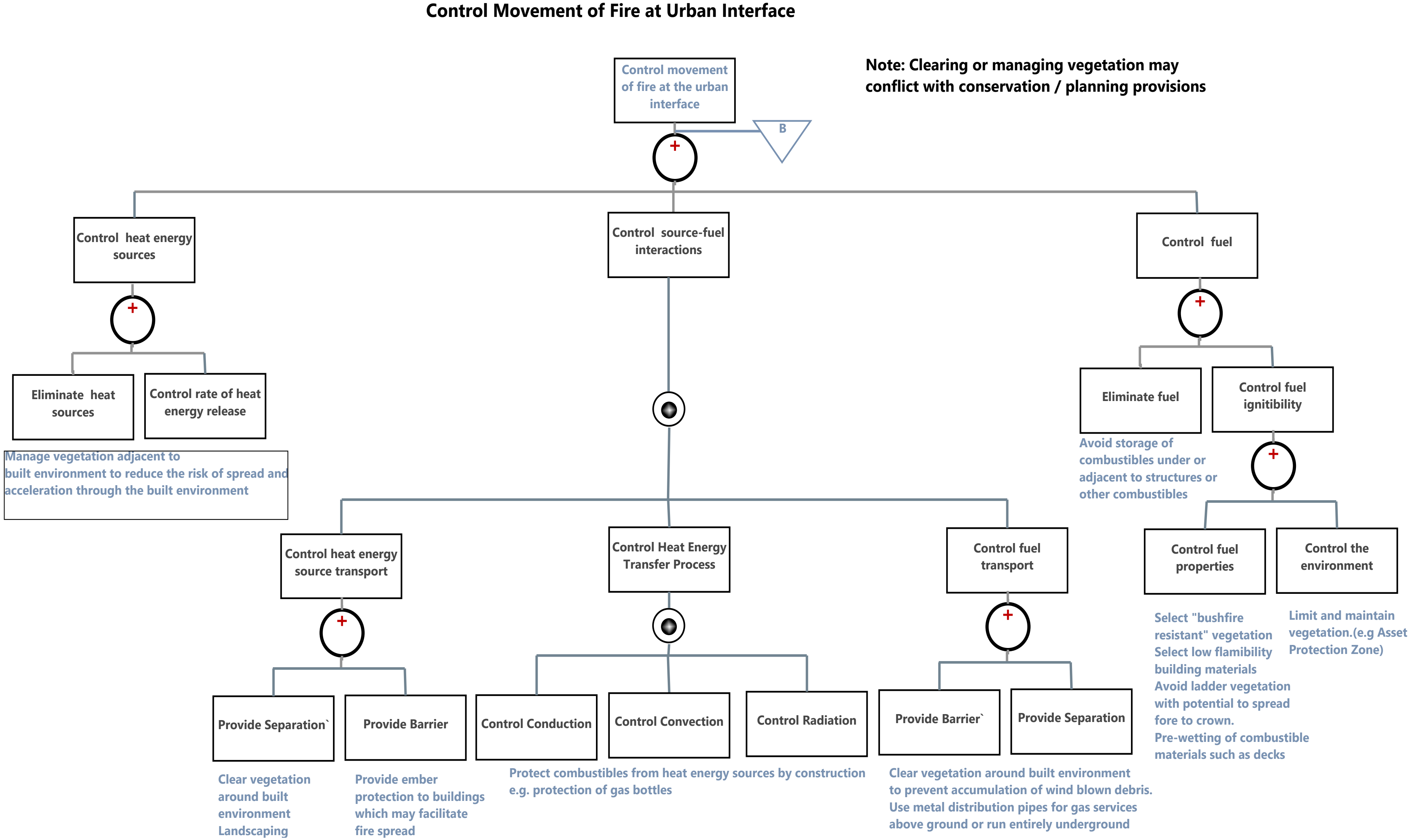


Figure 4.7 Manage exposed branch

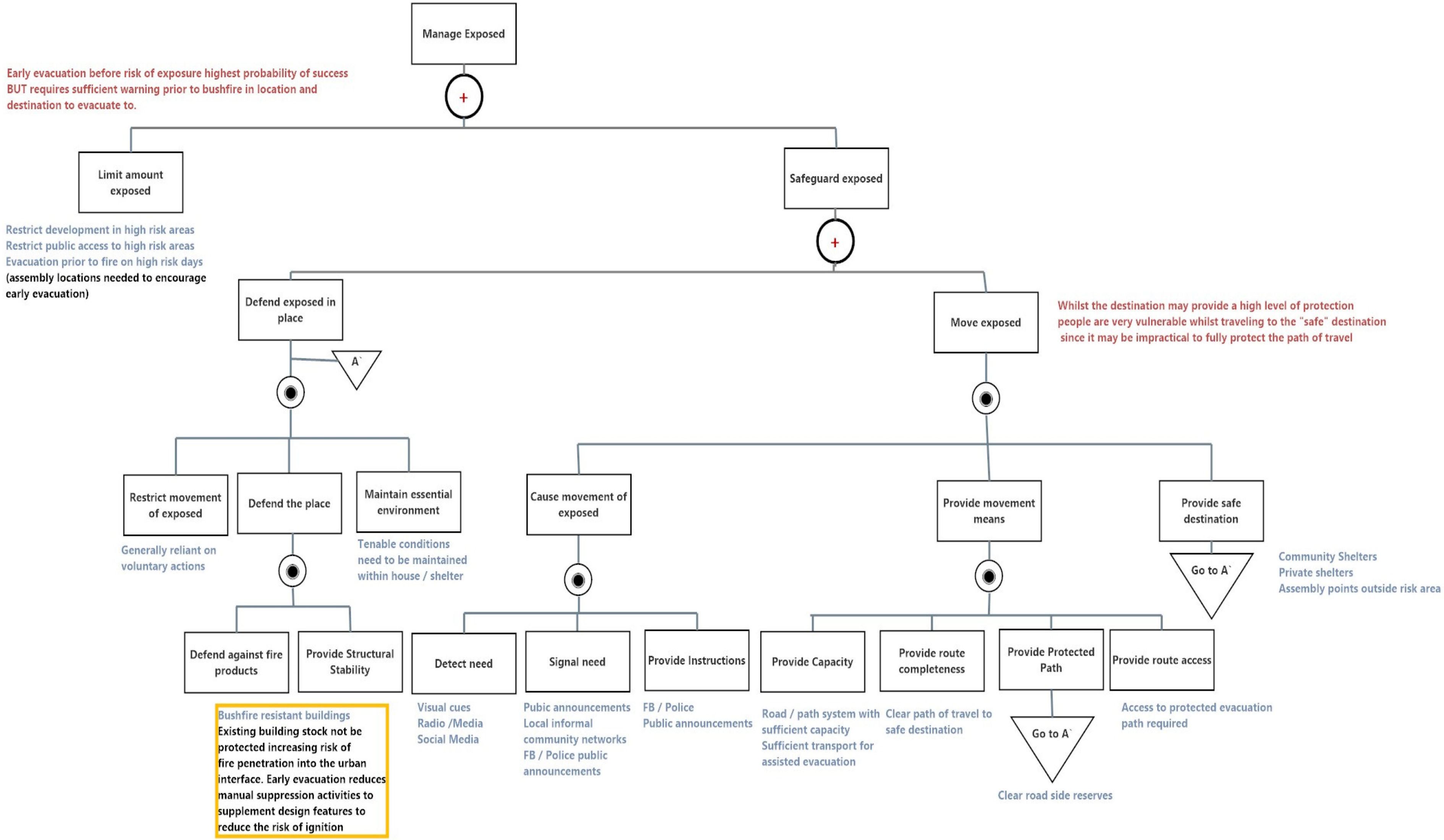
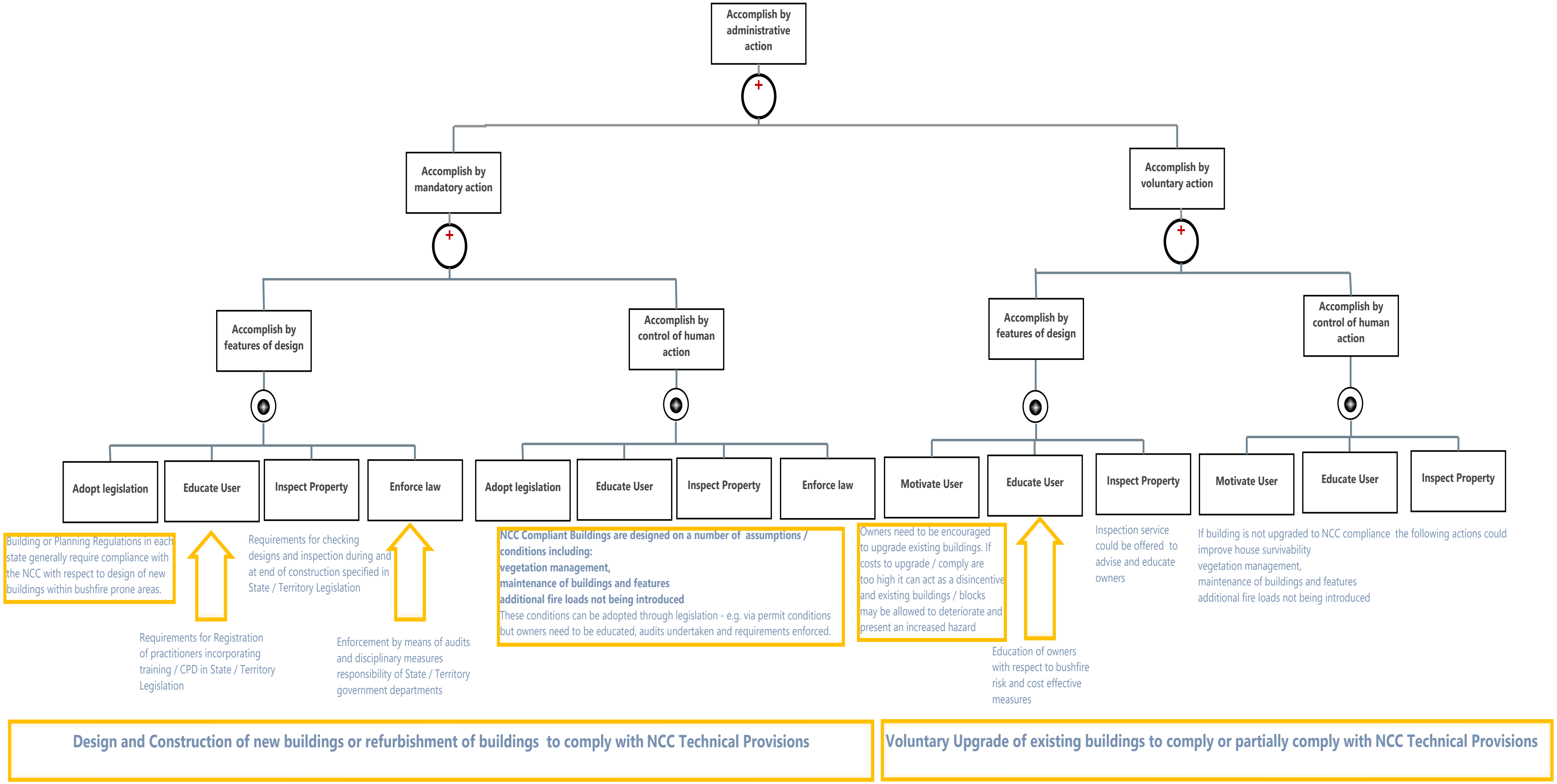


Figure 4.8 Accomplish by administrative action branch applied to design and construction of buildings in bushfire prone areas



5 Determination of Annual Probability of Exceedance (APE)

The APE for design actions is prescribed in Table GV5.1 of GV5 and Table V2.7.2 of V2.7.2. Table GV5.1 is reproduced below in Table 5.1.

Table 5.1: Annual probability of exceedance for design actions (NCC Volume One Table GV5.1)

Importance Level	Complex analysis APE for bushfire exposure	Simple analysis APE for weather conditions (design bushfire)
1	No requirement	No requirement
2	1:500	1:50
3	1:1000	1:100
4	1:2000	1:200

After determining the importance level of the building (Chapter 3) and selecting the type of analysis (Chapter 4), the appropriate APE is selected.

Example: A Class 2 building housing more than 12 occupants

From Table 5.1, the building is classified as importance level 3.

If the simple analysis method has been selected, the APE based on weather conditions would be 1:100.

If the complex analysis method has been selected, the APE for exposure to bushfire attack for design purposes would be 1:1000.

6 Determination of design actions

6.1 Chapter organisation

Sections 6.1 to 6.7 provide general information that is applicable to both the simple and complex types of analysis.

Section 6.8 provides specific guidance in relation to complex analysis and Section 6.9 provides specific guidance in relation to simple analysis.

Whichever type of analysis is adopted, the approach to the specification of bushfire design actions will be similar. General advice applicable to complex and simple analysis is provided in Section 6.10.

6.2 Overview of bushfire design actions

Verification Methods GV5 and V2.7.2, specifically require consideration of the following bushfire design actions for both the simple and complex approaches.

> (d) …
>
> (ii) Design bushfire conditions that include combinations of the following actions appropriate to the distance between the building and the bushfire hazard:
>
> (A) Direct attack from airborne burning embers.
>
> (B) Burning debris and accumulated embers adjacent to a building element.
>
> (C) Radiant heat from a bushfire front.
>
> (D) Direct flame attack from a bushfire front.

This approach is consistent with the NCC DTS requirements provided in AS 3959, Construction of Buildings in Bushfire-Prone Areas (Standards Australia 2018[21]), and the following referenced test standards for evaluation of the performance of elements of construction:

- AS 1530.8.1-2007 Methods for fire tests on building materials, components and structures - Tests on elements of construction for buildings exposed to simulated bushfire attack - Radiant heat and small flaming sources (Standards Australia 2007[19]).
- AS 1530.8.2-2007 Methods for fire tests on building materials, components and structures - Part 8.2: Tests on elements of construction for buildings exposed to simulated bushfire attack — Large flaming sources (Standards Australia 2007[20]).

6.3 Parameters for consideration

When establishing bushfire design actions, GV5 and V2.7.2 require consideration of reasonable variations in:

(e) …

(i) fire weather; and

(ii) vegetation; including fuel load, burning behaviour of the vegetation (including potential for crown fires); and

(iii) the distance of the building from vegetation; and

(iv) topography, including slopes and features that may shield; and

(v) ignition of adjacent buildings, building elements, plants, mulch and other materials; and

(vi) effective size of fire front; and

(vii) duration of exposure; and

(viii) flame height; and

(ix) flame tilt; and

(x) flame adhesion to sloping land; and

(xi) the height of the building and its elements.

Defining "fire weather"

Fire weather is typically expressed through some combination of surface air temperature, precipitation, relative humidity and wind speed. These meteorological variables are commonly combined into a single index using empirical relationships such as the McArthur Forest Fire Danger Index or the Grassland Fire Danger Index.

"Reasonable" variations in the design fire weather conditions are addressed through the prescribed APE specified in GV5 and V2.7.2. For the simple method, the APE for fire weather conditions are directly specified whereas for the complex method, fire weather is one of a broader range of parameters considered when defining the APE bushfire exposure.

6.4 Bushfire models for determination of design actions

The extent of exposure of a building element to bushfire attack is primarily dependent upon the proximity to the fire front, fire severity / fuel characteristics, fire weather, topography and shielding (by natural features or man-made barriers).

Close to the fire front there is potential for direct flame attack on a building. Topography and wind effects can tilt the plume towards a structure even if vegetation in the immediate vicinity has been cleared.

Beyond the distance at which there is potential for direct flame impingement / convective heating, a building element can be exposed to substantial radiant heat unless the element is shielded by another part of the building or some form of barrier.

For elements that are not shielded, the peak radiant heat flux level generally reduces as the distance from the fire front increases.

Embers / brands can be carried substantial distances via the convective plume but the concentration of embers / brands, and hence associated hazard, decreases (generally exponentially) as the distance from the fire front increases.

Bushfire models can be used to derive bushfire design actions with respect to exposure to embers, radiant heat and flame contact from the fire front or combinations taking into account the parameters listed above with supplementary exposures applied to address secondary fires as appropriate (refer Section 6.5 for further information on secondary fires).

Example: Bushfire model (e.g. AS 3959:2018 (Standards Australia 2018[21]))

A typical example of the use of a bushfire model to determine bushfire design actions is the method documented in AS 3959:2018 (Standards Australia 2018[21]) in conjunction with the AS 1530.8 test methods (Standards Australia 2007[19, 20]), which define the associated bushfire exposures. Further details of the AS 3959 model and derivation of design fire exposures are provided by England et al (2006[10]).

Chen and McAneney (2010[9]) analysed building losses based on the distance from adjacent bushland after major fires. Their findings are shown in Figure 6.1, which plots the percentile of all destroyed buildings against distance from adjacent bushland with and without the Duffy fires. The samples (destroyed buildings) were from the following fires:

• Marysville	Vic
• Kinglake	Vic
• Duffy and Como-Jannali	ACT / NSW
• Otway Ranges	Vic
• Hobart.	Tas

The Duffy fires differed substantially from other major bushfires with building losses extending further into the built environment.

Based on these distributions it can be observed that typically 40% of house losses occur within 10m of the “bushland”, 60% within 30m, over 70% within 50m, 85% within 100m and approximately 95% within 150m.

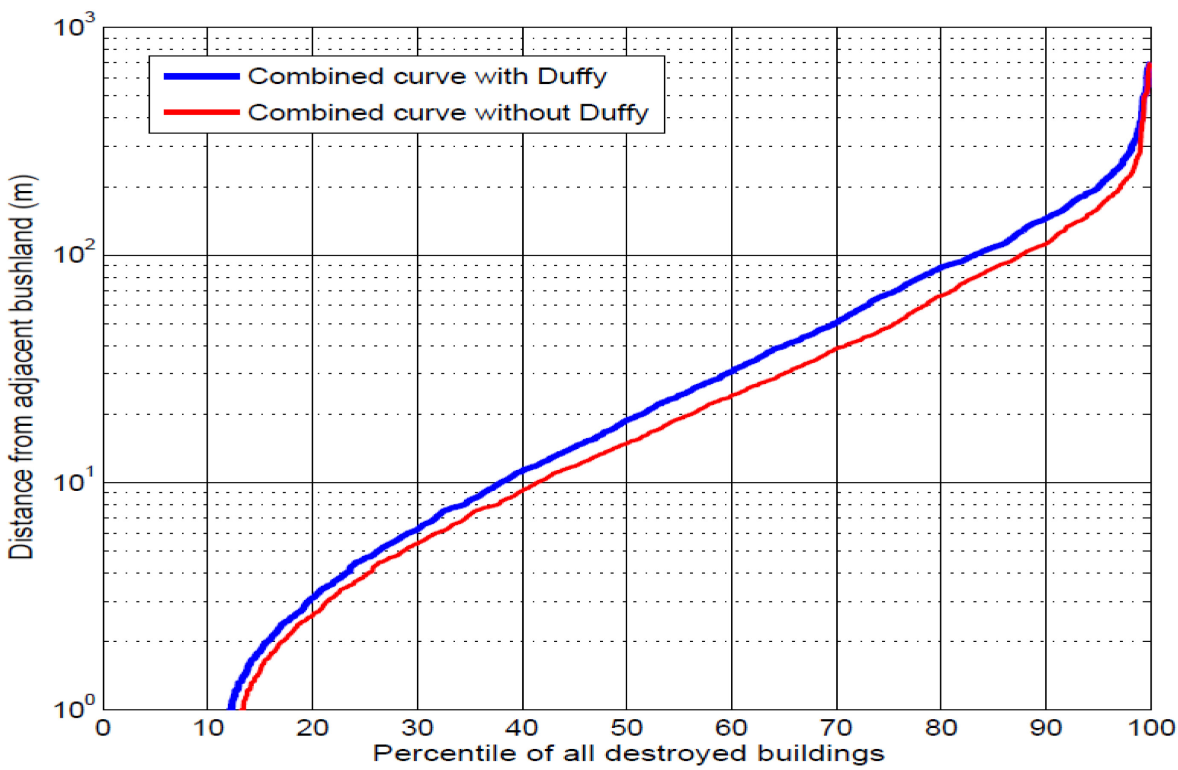
Therefore, it is considered reasonable to require consideration of vegetation up to 150m.

Note: the complex method does consider vegetation in the broader geographic region to determine the probability of spread to the urban interface.

Consideration of the impact of vegetation on bushfire design actions

If a form of vegetation does not encroach within 150m of the building under consideration, its contribution to the design actions need not be considered except for some buildings of importance level 4 where protection from ember attack and associated secondary fires may be considered beyond 150m of the vegetation if it is impractical to evacuate the occupants.

Figure 6.1 Cumulative distribution of all buildings destroyed in various major bushfires in Australia in relation to distance from nearby bushland from Chen and McAneney (2010[9])



6.5 Secondary fires

Secondary fires can vary greatly in size and duration depending upon the characteristics of the burning items involved in the secondary fire.

England et al (2006[10]) identified the following secondary fires scenarios:

- Wind-blown debris collecting on predominantly horizontal surfaces adjacent to building elements
- Adjacent structures (e.g. adjacent houses and outbuildings)
- Stored materials adjacent to buildings
- Inappropriate vegetation adjacent to buildings.

The following are examples of methods of addressing secondary fire scenarios.

Example: Burning debris and accumulated embers

Since wind velocities will vary, it is generally necessary to assume debris will collect on all horizontal and close to horizontal surfaces, roof valleys and similar details. Where these details cannot be avoided, burning debris can be characterised by the timber cribs specified in AS 1530.8.1 if more specific data is not available.

Note: Innovative design of buildings to minimise the accumulation of embers (e.g. avoiding re-entrant details and horizontal surfaces and / or adopting aerodynamic forms that tend to shed windblown debris and embers) could form part of a building solution for evaluation using the Verification Method.

Example: Exposure to adjacent structures (fire spread between buildings)

Fire spread between buildings is required to be addressed under NCC Volume One CP2 and NCC Volume Two P2.3.1 and has not, therefore, been included in GV5. The impact of this design action may be addressed for Volume One using CV1 and CV2, or an equivalent process. Fire spread between buildings during bushfire events should be evaluated without consideration of fire brigade intervention (refer Section 6.6 for further information on fire brigade intervention).

The hazards caused by stored materials, mulch and inappropriate vegetation, are commonly addressed by administrative means through placing controls on the location of these hazards close to a building (this approach is consistent with assumptions underpinning AS 3959:2018[21]). Where controls are not specified, the expected heat release rate from the stored materials, mulch or vegetation should be determined and the response of the building to these design actions evaluated.

Simultaneous exposure to secondary fires

When determining bushfire design actions, it should be assumed that any secondary fires occur simultaneously with the peak exposure directly from the fire front.

A.2 Intervention by fire brigades and occupants

During significant bushfires, there will be conflicting demands on fire brigade resources and reliance should not be placed on fire brigade intervention to protect a specific property.

Prior to the 2009 Black Saturday fires, an early evacuation or stay and defend policy was in place and data from major fires indicated that the presence of occupants significantly increased the probability of house survival (refer Table 7.1). However, in response to the subsequent Royal Commission findings there is now a greater emphasis on early evacuation. Whilst this is expected to reduce fatalities by reducing the numbers of people at risk, a negative consequence will be an increase in property losses for buildings constructed to similar standards. It should therefore be assumed that there will be no fire brigade or occupant intervention with respect to protecting a specific property.

Fire brigade or occupant intervention

When determining design fire actions and / or the responses of elements of construction no modification should be made to take into account fire brigade or occupant suppression activities. (Note: This includes manually operated sprinkler suppression systems since occupants are expected to have evacuated substantially before the arrival of the fire front, although in some circumstances it may be reasonable to consider the effects of pre-wetting combustible materials and vegetation).

A.3 Impact of wind

Ramsay and McArthur (1987[14]) noted that "severe bushfires are commonly accompanied by high winds due to the prevailing weather conditions and localised high winds can be induced by the fire, potentially "opening the buildings up" prior to the passage of the fire front by dislodging roof tiles and breaking windows, increasing susceptibility to ember / flying brand attack".

The resistance of the structure / building envelope to high winds will normally be addressed as part of the structural design of a modern building. However; it is still necessary to consider the impact of wind on design actions (e.g. flame inclination, pressure distributions applied to structures, ember concentrations and velocities) and the behaviour of combustible elements.

Weather conditions can vary rapidly, and local topography and other factors lead to localised variations especially relating to wind velocities. Therefore, the impact of a range of wind velocities shall be considered under the design actions, as far as practicable. It is understood that there are practical limitations and methods of addressing some of these limitations are discussed in Chapter 7.

Wind variability

Due to the variability of wind during a bushfire event it is necessary to consider the impact of variable wind velocities when determining design actions, having regard for practical limitations.

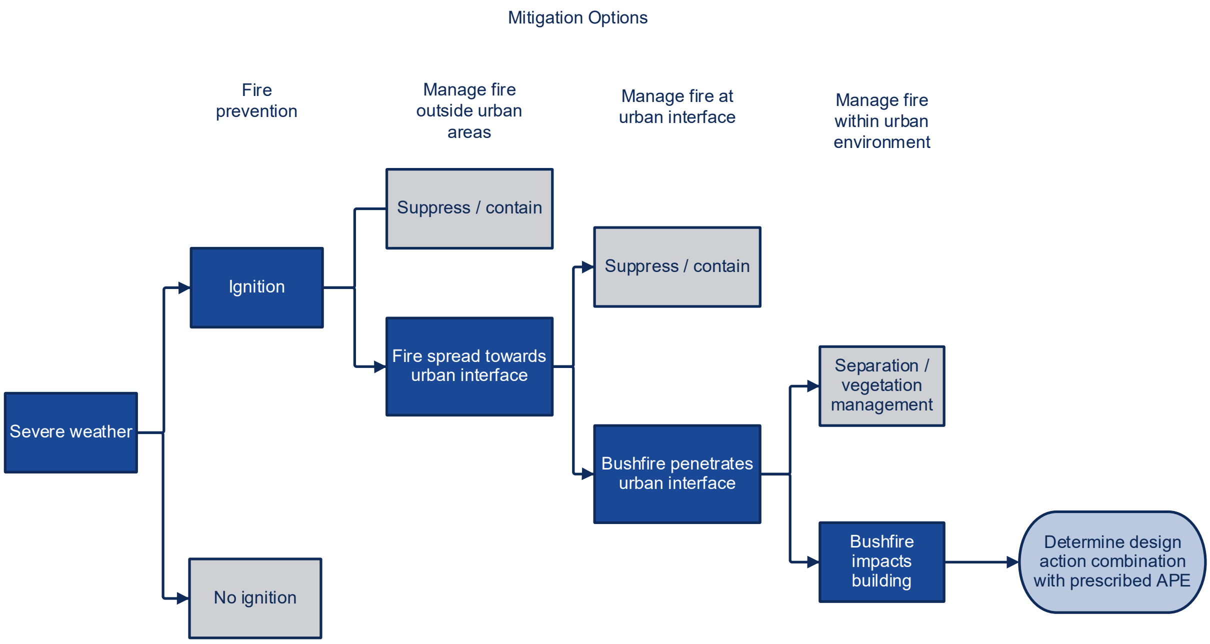
6.6 Complex analysis

Exposure of a structure to a bushfire event does not occur as a result of extreme weather conditions alone, but rather as a result of a series of related events as indicated in the simple event tree shown in Figure 6.2, which has been derived from the fire safety concepts tree analysis and is consistent with the following requirement from the Verification Method:

Note: Table GV5.1

Complex analysis must consider the probability of ignition, fire spread to the urban interface and penetration of the urban interface coincident with fire weather conditions.

Figure 6.2 Determination of exposure to design actions - complex method



The main advantage of the complex analysis method is that it enables a broader range of parameters to be considered when deriving design actions, encouraging the design of buildings solutions tailored to the specific risks at a particular location.

It also encourages, and takes account of, other mitigation methods such as fire prevention and fire management across a geographic region that may fall under different legislation. Opportunities to take advantage of this flexibility may be limited for infill developments, but can be considered for new housing estates and large facilities where fire breaks and fire prevention features such as below ground power cables are used.

There are opportunities to combine the application of the complex analysis approach with general planning and bushfire mapping activities. There is potential to improve the consistency of approaches throughout a township or suburb, and determine design bushfire exposures that more accurately reflect the bushfire risk as described in the example below.

Example: Integration of complex analysis with mapping bushfire exposures

Using the complex approach, the design fire weather conditions for a township could be derived, or bushfire design actions specified with regards to the bushfire hazard for individual allotments, or groups of allotments in the specific township or suburb. Bushfire exposures could be expressed in terms of Bushfire Attack Levels (BAL) for compatibility with the AS3959 approach. Such an approach could also negate the need for subsequent individual assessments for an individual development and provide consistency throughout a township or suburb.

The event tree shown in Figure 6.2 is consistent with a number of quantitative bushfire risk assessment models under development (e.g. Atkinson et al (2010[6]), Cechet et al (2014[8])). Earlier work by Bradstock and Gill was referenced by Atkinson et al (2010[6])), which proposed the relationship:

D=I.S.E.G.H.

Where:

D is the adverse risk to humans and property
I is the probability of ignition in the landscape
S is the probability of the fire reaching the urban Interface
E is the probability of the fire encroaching into the built environment
G is the probability of fire propagating within the built environment
H is the probability of fire propagating within buildings.

This relationship identifies similar events to the above event tree except that it goes further and considers the probability of fire propagating within buildings. The probability of fire propagating within buildings is also considered in GV5 and V2.7.2 (refer Chapter 7).

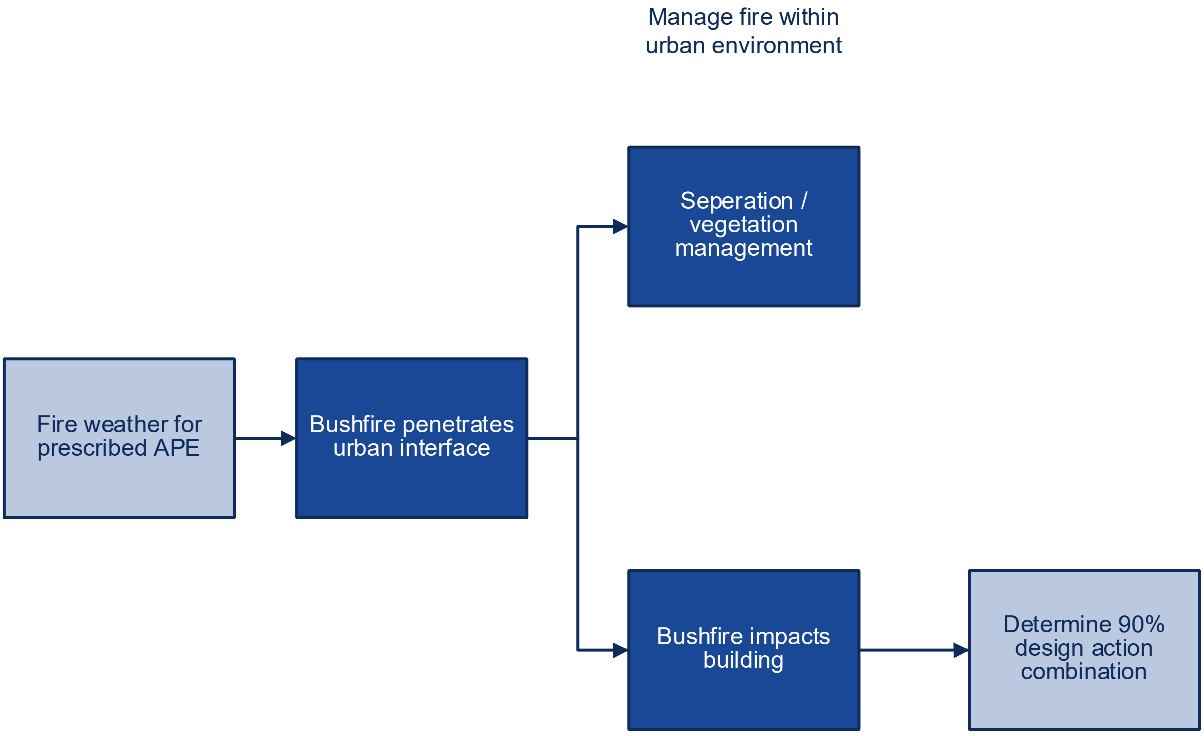
6.7 Simple method

The simple analysis method avoids the need to consider fire behaviour over a large area by specifying an APE for the fire weather, and assuming that when these conditions occur the fire will penetrate the urban interface as shown in Figure 6.3.

The 90-percentile bushfire exposure combination is then used to determine the bushfire design action combination.

This approach is consistent with the DTS approach specified in AS 3959:2018 but in some circumstances, may tend to be overly conservative particularly where the bushfire hazard is relatively low.

Figure 6.3 Determination of exposure to design actions - simple method



6.8 Specification of bushfire design actions

6.8.1 Introduction

The specification of design actions to some extent will be dependent upon the proposed methods used to determine the response of elements or combinations of elements to the design action.

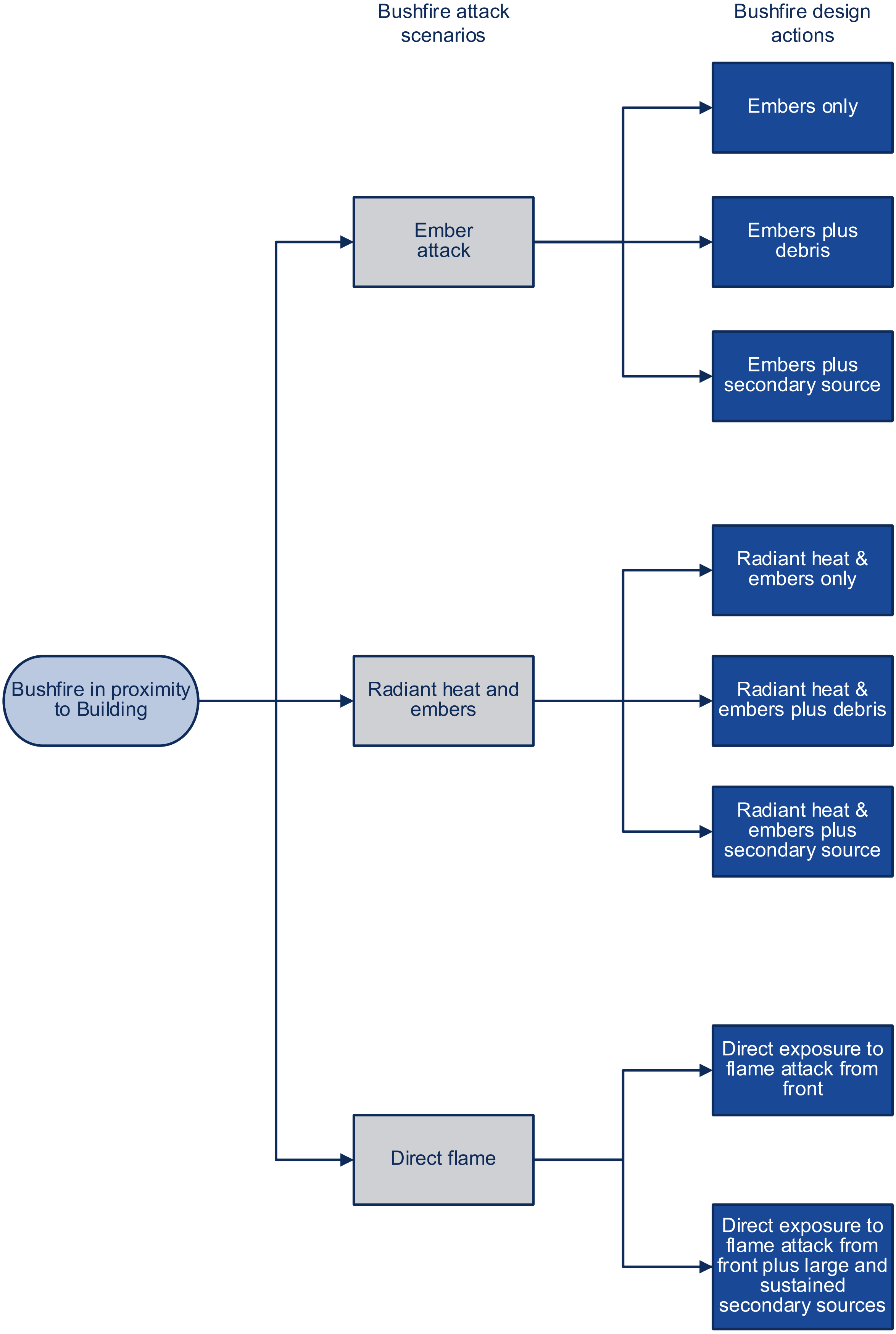
Irrespective of the methods adopted bushfire exposures will generally need to be rationalised to some extent to facilitate comparison and evaluation of the performance of elements of construction.

A typical rationalisation is shown in Figure 6.4. Since the Verification Method assumes no involvement of fire brigade or occupants, the time related events involving human interventions (such as suppression and evacuation) are not required for determination of compliance with the Verification Method. This avoids the need to adjust the bushfire actions to take into account suppression activities.

The following sub-sections provide further information relating to the specification of bushfire design actions.

Where appropriate, reference has been made to published data from Project Vesta (2008[12]), which was an investigation into the behaviour and spread of high-intensity bushfires in dry eucalypt forests. It was designed to quantify age-related changes in fuel attributes and fire behaviour in dry eucalypt forests typical of southern Australia.

Figure 6.4 Bushfire design actions



6.8.2 Ember (fire brand) attack

Typically, fire brand densities have been found to decrease exponentially downwind of a fire break.

Project Vesta (2008[12]) suggested the following general relationship for fires where the convective column collapsed on reaching the fire break:

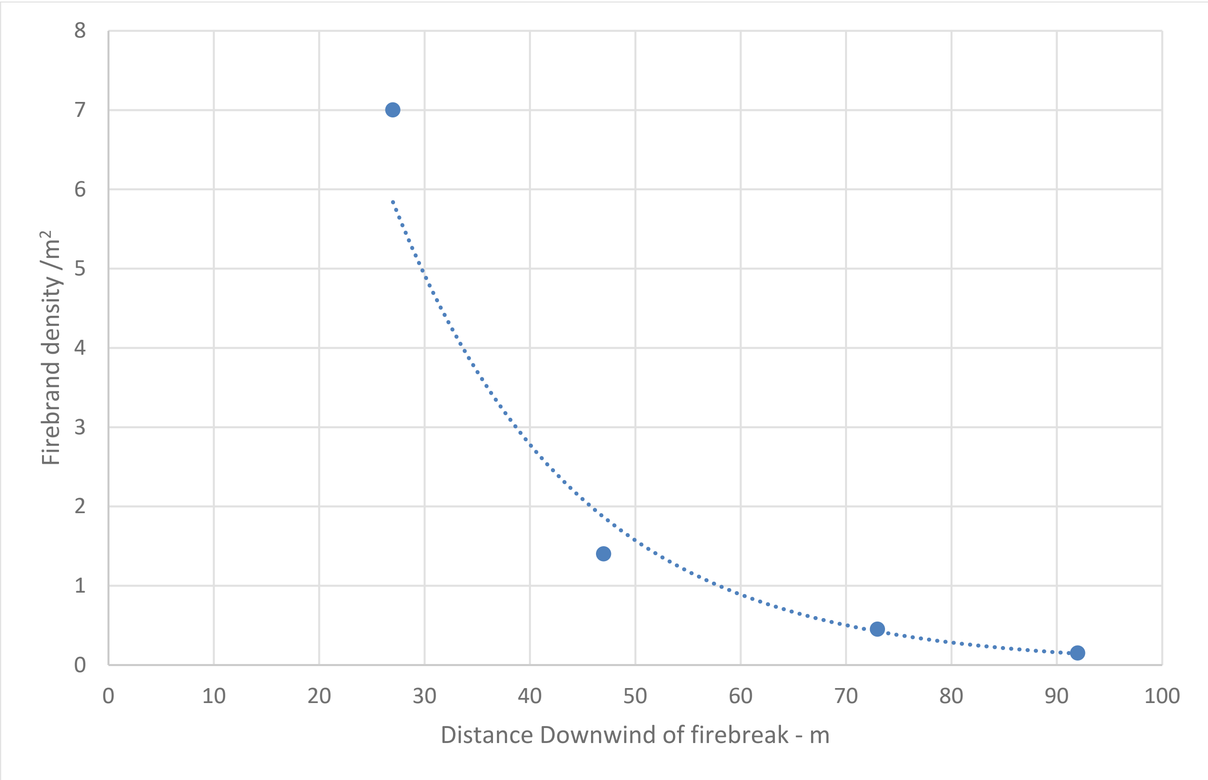
$D_{Fb}=D_o\ e^{-ad}$

Where,

D_{Fb} is the fire brand density / m^2 at a given distance d
D_o is the fire brand density / m^2 immediately downwind of the fire break
a is a constant describing the rate of decrease of fire brand density with distance
d is the distance downstream of the fire break.

An example of the data obtained from Fire D 5-year-old fuel is shown in Figure 6.5.

Figure 6.5 Maximum fire brand density downwind of Fire D (Jarrah forest with 5-year-old fuel) adapted from Gould et al (2008[12])



Higher fire brand densities were obtained from fires using 22 year old fuel.

The Project Vesta report (2008[12]) also includes descriptions of the nature of the fire brands formed and proposed relationships for fire brand distribution at right angles to the prevailing wind direction.

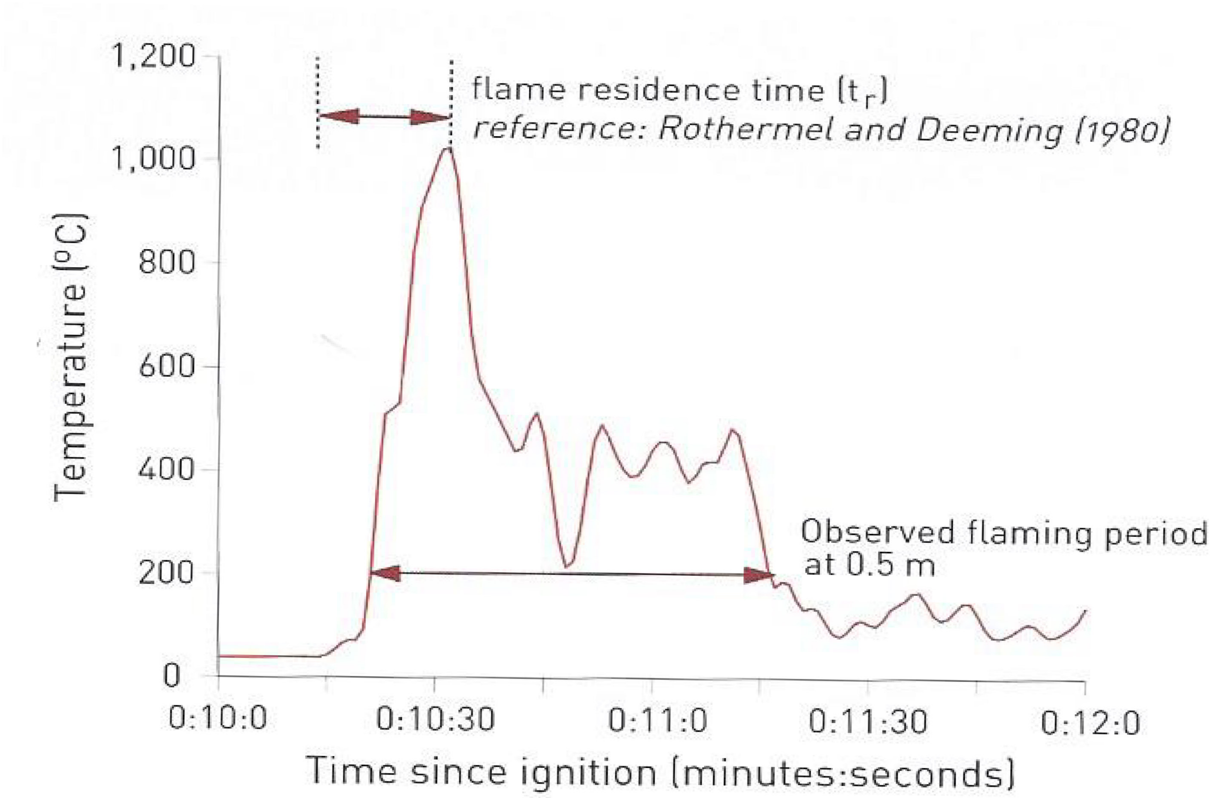
Subject to availability of data, it is possible to estimate fire brand density based on the distance from the fire front and from consideration of the fire brand characteristics, which can then be used to estimate the probability of ignition of secondary fires or embers penetrating openings.

A simple conservative approach, adopted by the NCC DTS Provisions in AS 3939:2018 is to assume that buildings within 100m of the fire front are exposed to significant ember attack rather than considering the ember (fire brand) exposure density.

6.8.3 Radiant heat attack

Estimates of imposed radiant heat can be made based on measured radiation exposures from field experiments. However, such data is limited and approximate estimates are commonly based on assumed flame heights and estimated emitted radiant heat flux levels. The exposure period at maximum heat flux is important and is commonly taken as the flame residency period. This can be defined as the time from initial temperature rise to the time of definitive drop as suggested by Rothermel and Deeming (1980[16]). A typical time temperature history from Project Vesta (2008[12]) is shown in Figure 6.6 with a flame residency period of approximately 20 seconds and an observed flaming period approaching 1 minute. Since the emitted heat flux is proportional to temperature to the power 4 the longer observed flaming period is less critical.

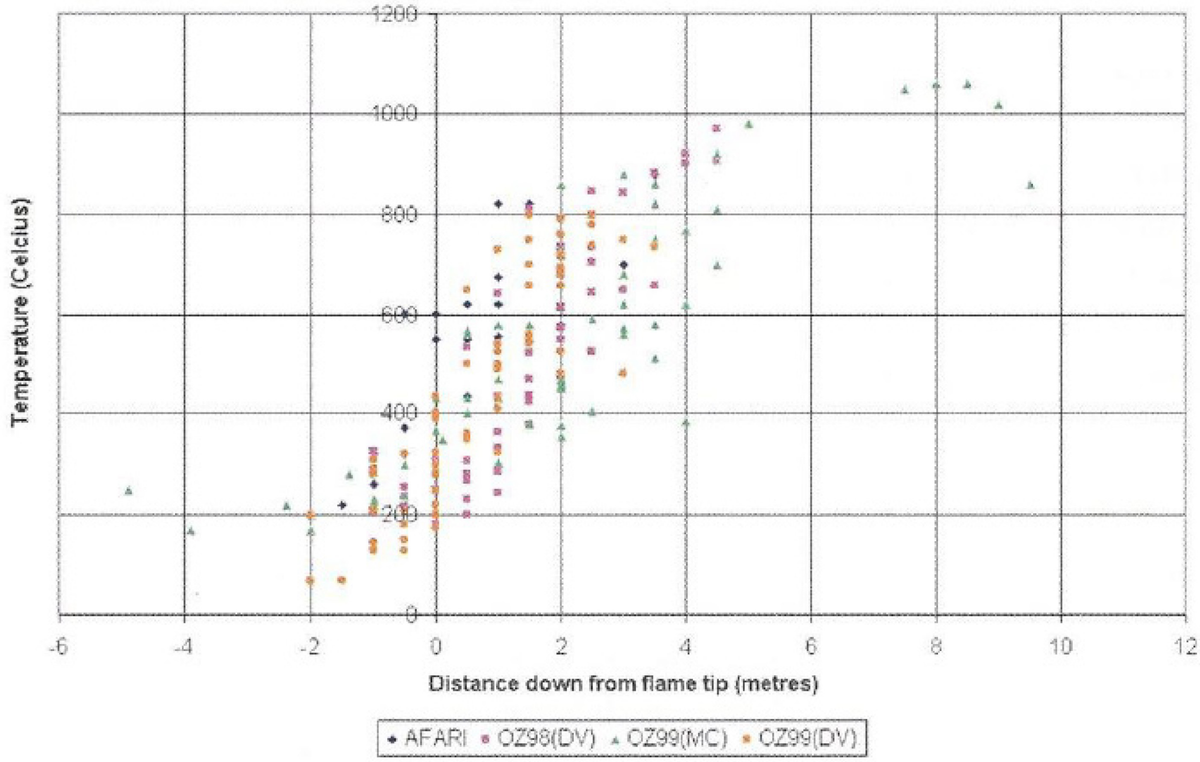
Figure 6.6 Flame residency time and the observed flaming period at 0.5m 75m from ignition line (fire Mc 08/A) from Gould et al (2008[12])



Project Vesta confirmed previous findings that showed by using the flame tip as the datum for the thermocouple positions within the flame, a consistent relationship between flame temperature and distance from the flame tip can be obtained over a large range of flame lengths. It appears to be linear over much of the range of experimental data as shown in Figure 6.7, which has been extracted from Gould et al (2008[12]).

This indicates that the measured temperatures at the estimated position of the tip of the flame varied from approximately 200 to 400°C (473 to 673K) for the data from dry eucalypt forests increasing to a peak temperature between 800 and 1050°C (1073 to 1323K) close to ground level.

Figure 6.7 Flame temperature plotted against distance below the flame tip based on data from Project Vesta tests and data from grass fire tests in Kenya provided by the Canadian Forest Service from Gouldet al (2008[12])



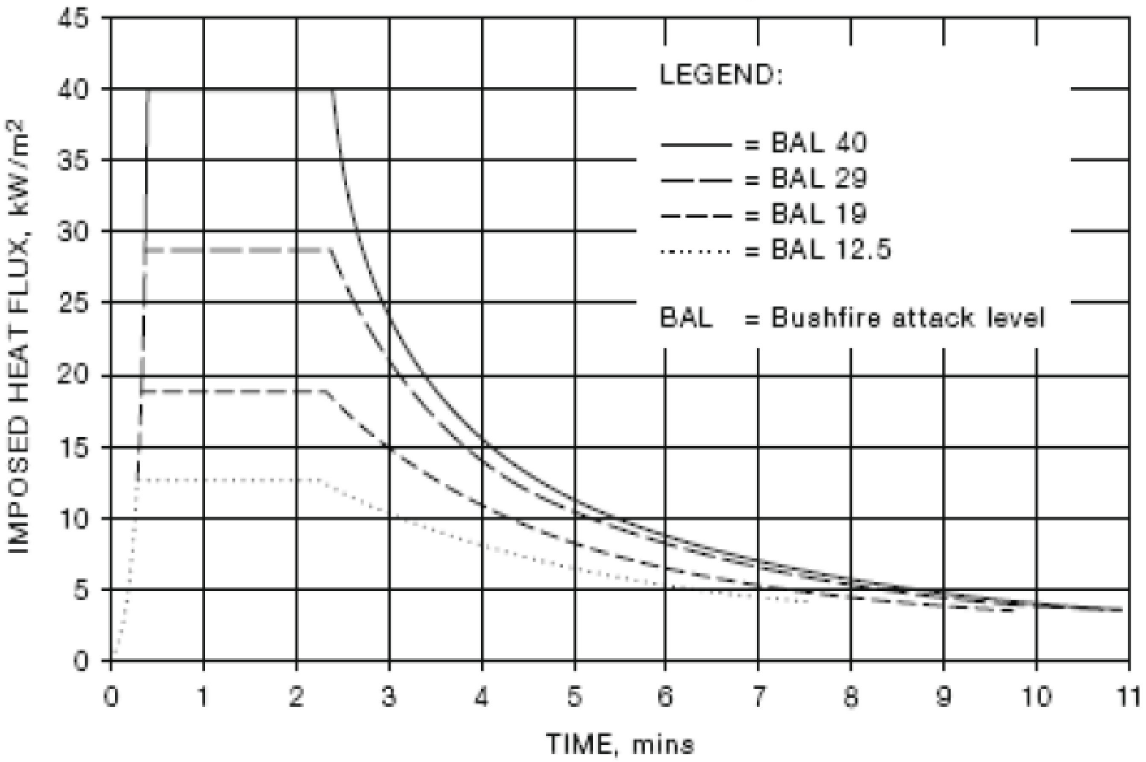
The NCC DTS approach within AS 3959 adopts a simplified method by calculating the flame height and assuming a uniform emitted heat flux over the total flame height (flame temperature of 1090K and emissivity of 0.95) over a default fire front width of

100m with a flame residency period (maximum emitted heat flux) of 2 minutes defined by AS 1530.8.1 together with the heating profiles shown in Figure 6.8.

The DTS approach also adopts a flame inclination that maximises heat transfer between the fire front and building rather than considering the effect of wind and will therefore over-estimate the imposed heat flux in most situations.

Irrespective of the approach adopted to derive the exposure to radiant heat, in many instances it will be convenient to use the AS 1530.8.1 Bushfire attack levels for evaluation of the performance of elements of construction.

Figure 6.8 Imposed heat flux from AS 1530.8.1[19] for various Bushfire Attack Levels (BAL)

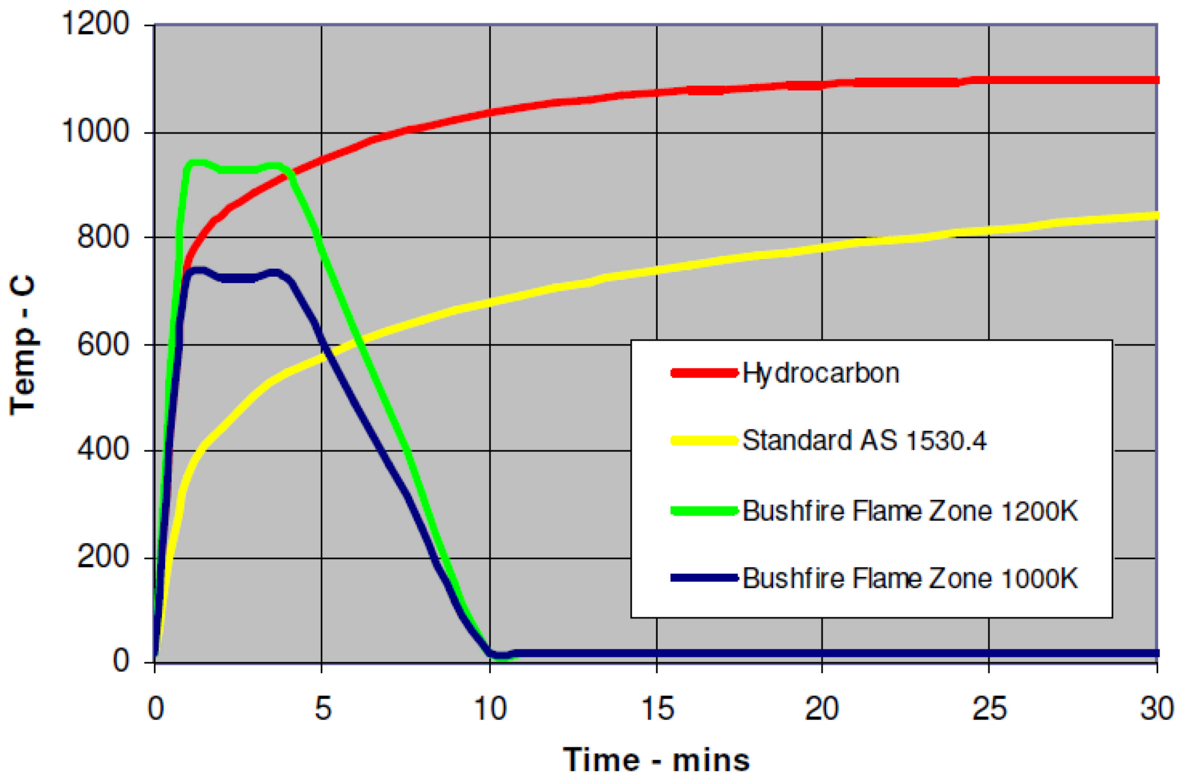


6.8.4 Direct flame exposure

If the fire front is close to a building, direct exposure to flames / convective heating may occur particularly on a sloping site and if strong winds are present tending to tilt the flame towards the ground. The full exposure is likely to approximate the flame residency period, but depending upon the proximity, heavy fuels may extend exposure or major secondary fires may be ignited adjacent to the structure.

A similar profile to Figure 6.8 can be generated with a rapid rise, sustained peak and decay period using assumed flame temperatures as shown in Figure 6.9.

Figure 6.9 Direct flame exposure conditions based on assumed flame temperatures and heating profile of AS 1530.8.1



The standard fire resistance test and hydrocarbon heating regimes from AS 1530.4:2014 (Standards Australia 2014[18]) are provided for comparison.

For the NCC DTS approach, AS 1530.8.2 is referenced, which uses the AS1530.4 standard heating regime with 30 minutes exposure. Whilst a closer simulation could be achieved by adopting the hydrocarbon regime for a period of approximately 5 minutes plus a cooling period, the standard heating regime over a longer period was adopted because furnace control during the first 5 minutes of a hydrocarbon test would not be expected to be precise, leading to excessive variations in exposure conditions from one test to another.

From Figure 6.9, it can be seen that the thermal shock is not as great with the standard heating regime and a peak temperature of 841°C is attained after 30 minutes. Supplementary controls on vegetation immediately around a building may reduce the flame temperature close to the point of contact and severity of exposure significantly and therefore in many circumstances the peak temperature will not be critical. The extended duration of heating (30 minutes) can also account for heavy fuels or secondary fires that may extend exposure.

6.8.5 Debris

On surfaces where debris can collect there is a significant risk that embers could ignite accumulations of debris. A practical approach to quantify this exposure is to establish a mass burning rate and if the performance of an element cannot be predicted the exposure can be simulated by burning cribs. This approach is adopted in AS 1530.8.1.

During the development of AS 1530.8.1, a series of tests were performed on typical samples of burning debris to ascertain the mass burning rate with and without imposed radiant heat. A typical example is shown in Figure 6.10.

Figure 6.10 Determination of mass burning rate for debris when exposed to radiant heat: England et al (2008[11])

The mass loss rates were compared against similar tests undertaken with three sizes of timber crib.

For this application, timber cribs have the following advantages over gas burners:

- As the cribs are consumed, large concentrations of burning timber embers of varying sizes are produced, which can lodge or fall through gaps simulating a major ignition process for homes exposed to ember / burning debris attack.
- The crib itself provides a high localized heat flux of similar magnitude and duration to that expected from a pile of burning debris or mulch adjacent to a building façade or on a horizontal surface such as a deck simulating an ignition process for buildings involving the collection of debris and mulch on or adjacent to the element of construction.

6.8.6 Other secondary fires

Similar approaches can be adopted for other secondary sources to that described for debris above. Data is available in technical publications for burning rates of many items that may be involved in secondary fires, which can be used to define design fires.

For fire spread between buildings, the criteria specified in CV1 and CV2 of NCC Volume One can be used to define the required exposure.

7 Determination of response to bushfire attack

7.1 Overview – Determination of the response of elements of construction to bushfire attack

Once the design actions have been derived, the next stage in the design process is to determine the response of the elements of construction or combinations of elements to enable the probability of fire initiation within the building when exposed to design actions to be determined.

This should then be compared with the acceptance criteria that requires the probability of fire initiation within the building not to exceed 10%.

Verification Methods GV5 and V2.7.2 require the assessment process to include consideration of the following:

> (f) …
> (i) the probability of non-complying construction of critical aspects of an approved design; and
> (ii) the probability of critical aspects of an approved design being fully functional during the life of the building; and
> (iii) the inclusion of safety factors; and
> (iv) sensitivity analysis of critical aspects of the proposed design.

The scope of the NCC is limited to the provision of national technical provisions with the administration and maintenance of building works being the responsibility of the States and Territories. Therefore, the NCC Verification Method specification of a maximum 10% probability of fire initiation within the building has to be based on compliant construction of critical aspects of the approved design and ongoing maintenance of the critical aspects of the design such that the design performance is maintained.

However, this does not absolve designers, suppliers and regulatory authorities of responsibility for addressing safety throughout the building life cycle and hence the inclusion of requirements within GV5 and V2.7.2 to highlight the need for consideration.

Section 8 provides supplementary information relating to administration of building works, compliance and maintenance.

Interpretation of acceptance criteria

The NCC Verification Method specification of a maximum 10% probability of fire initiation within the building should be based on compliant construction of critical aspects of the approved design and ongoing maintenance of the critical aspects of the design such that the design performance is maintained.

BUT GV5 and V2.7.2 also require consideration of the probability of non-complying construction of critical aspects of the approved design; and the probability of critical aspects of an approved design being fully functional during the life of the building.

The design must document how these matters have been addressed and estimated probabilities for compliant construction and maintenance of critical features, which should be considered by the relevant regulatory authority when reviewing the design. Further guidance relating to the Administration of Building Works, Compliance and Maintenance is provided in Chapter 8.

The response of elements of construction to bushfire attack can be evaluated using a number of methods or combinations of methods including:

- exposure to standard fire test methods
- analysis of bushfire loss data (statistical methods)
- analyses based on material properties and engineering methods
- expert judgement
- fire experiments.

The selection of the most appropriate method(s) will depend upon the specific circumstances, but for general applications, the specification of standard fire test methods provides the most design flexibility and simplifies the assessment of evidence of suitability.

The performance at the interfaces between elements of construction must be considered and may represent the most vulnerable part of the building envelope.

Wind exposure of a building is transient and may vary rapidly through the course of a bushfire. Wind exposure will be modified as the wind interacts with the building and other features. Testing under steady state conditions may yield unrealistic results and performance of many elements of construction may vary across a range of wind velocities. For example, burning behaviour of some combustibles will be enhanced at some velocities and retarded at others.

Ideally the behaviour of elements of construction should be evaluated over a broad range of air velocities and bushfire exposures, but in most instances it is impractical to determine the fire performance of building elements under a comprehensive range of wind conditions.

Designers should take account of the potential implications of likely variations in exposure conditions including the impact of wind variations and material variations when assessing the probability of failure. Uncertainties may be addressed through the adoption of conservative assumptions when deriving the design exposure conditions or in some cases explicit safety factors may be nominated.

Care needs to be taken with whichever approach is taken. For example, introducing large safety factors may have no impact if large unprotected openings are present in an element or if the bushfire exposure is substantially changed because vegetation is not managed in accordance with the design requirements.

For risk based approaches, sensitivity analyses may be more helpful in identifying features of a design that are more sensitive to changes in bushfire exposure or non-compliances so that the design can take this into account.

Common methods of determining the response of elements to bushfire attack are summarised in the following sections.

7.2 Standard test methods

Standards Australia published the following standards in 2007, which were subsequently referenced by AS 3959:2018 and therefore form part of the framework for the NCC DTS Solutions for construction in bushfire prone areas, but the methods are equally suited to use in performance designs:

- AS 1530.8.1-2007 Methods for fire tests on building materials, components and structures - Tests on elements of construction for buildings exposed to simulated bushfire attack - Radiant heat and small flaming sources.
- AS 1530.8.2-2007 Methods for fire tests on building materials, components and structures - Part 8.2: Tests on elements of construction for buildings exposed to simulated bushfire attack—large flaming sources.

The following performance criteria were specified in the test methods.

When exposed to the design bushfire conditions the building element shall not permit the following:

(a) formation of an opening from the fire exposed face to the non-fire exposed face of the element through which a 3 mm diameter probe can penetrate during the test and monitoring period (this indirectly assesses the risk of embers passing through openings)

(b) sustained flaming for more than 10 s on the non-fire side during the test and monitoring period

(c) flaming on the fire exposed side 60 minutes after the start of the test

(d) radiant heat flux 365 mm from the non-fire side of the specimen in excess of 15 kW/m^2 from glazed and un-insulated areas during the test

(e) mean and maximum temperature rises greater than 140 K and 180 K on the non-fire side respectively during the test and monitoring period, except for glazed / uninsulated areas for which the radiant heat flux limits are applicable

(f) radiant heat flux 250 mm from the fire exposed face of the specimen greater than 3 kW/m^2 between 20 minutes and 60 minutes after the commencement of the Part 1 test or 60 minutes after commencement of the Part 2 test (this was included to maintain egress paths from the building)

(g) mean and maximum temperatures of the internal faces of constructions including cavities exceeding 250°C and 300°C respectively between 20 minutes and 60 minutes after the commencement of the Part 1 test or 60 minutes after commencement of the Part 2 test.

The principle of Part 1 is that a representative element of construction is subjected to an imposed radiant heat flux in conjunction with small flaming sources. The radiant heat flux is varied with time to simulate the passage of the flame front. During the test, a pilot ignition source is applied to exposed combustibles and volatiles on the exposed face, simulating ember attack. Burning cribs are also applied on surfaces where there is potential for debris accumulation. The exposure conditions have been previously discussed in Section 6.10.

The results are expressed in terms of Bushfire Attack Levels (BAL).

For example, a specimen tested in accordance with AS 1530.8.1 that satisfied the following performance criteria at a peak heat flux of 40 kW/m^2 with a Class A crib, would be classified as BAL: A40. Part 2 applies to elements potentially exposed to full flame engulfment from the fire front and utilises the standard heating regime of AS 1530.4:2005 in lieu of the burning cribs and radiant heat. It can also be applied to large secondary fires.

For a specimen tested in accordance with AS 1530.8.2 that satisfied the appropriate performance criteria, the element of construction would be classified as BAL: FZ.

Reference should be made to the AS1530.8 standards (Standards Australia (2007[19, 20]) and England et al (2008[11]) for further information.

Whilst the test methods do not specifically address wind, the following observations indicate how the test methods compensate for this to the degree necessary to demonstrate compliance with the DTS Provisions:

- penetration of the façade by embers is addressed by limiting gap sizes
- conservative assumptions have been made deriving the test exposure conditions (refer Section 6.10)
- self-extinguishment of the exposed façade is required after exposure to the heating regimes.

7.3 Bushfire loss data and incidents

Whilst investigations and surveys after bushfires can include subjective interpretations with respect to matters such as the behaviour of elements, extent of human intervention and the compliance of the building at the time of the fire, they can provide useful data particularly if the sample size is adequate to provide confidence in the results.

A good example of the types of information available is shown in Table 7.1, which was extracted from the results of Surveys in the Otway Ranges after the Ash Wednesday fires presented by Ramsay et al (1996[15]).

Table 7.1 Relative risks from Ramsay et al (1996[15])

Items	Options	Relative Risk of Destruction
Wall Cladding	Timber	1.0
Wall Cladding	Fibre cement	0.8
Wall Cladding	Masonry	0.4
Roof Cladding	Steel	0.7
Roof Cladding	Tiles	0.4
Roof Cladding	Corrugated iron	0.9
Roof Cladding	Fibre cement	1.0
Roof Slope	Pitched >12º	0.8
Roof Slope	Flat < 12º	1.0
Elevation	Slab on Ground	0.2
Elevation	High >2m	0.4
Elevation	Low <2m	0.5
Elevation	Stumps	1.0
Occupant Action	Stayed	0.1
Occupant Action	Left, returned within 30 minutes	0.4
Occupant Action	Left and stayed away	0.6
Occupant Action	Unoccupied - at the time of fire	1.0
Surrounding Veg.	Grass	0.1
Surrounding Veg	Shrubs	0.4

Items	Options	Relative Risk of Destruction
Surrounding Veg	Trees	1.0

7.4 Calculation / modelling

In some instances, the performance of elements of construction can be predicted based on engineering calculations or modelling using material properties for the barrier systems where adequate information is available at elevated temperatures. Care needs to be taken when adopting these methods with respect to joints and interactions with other materials where differential expansion may cause gaps to open.

For some elements of construction where the fire-resistant properties are well documented. Calculation results may be able to be calibrated against test results for a range of exposure conditions providing further confidence in calculations.

Methods available may vary from simple hand calculations to finite element models.

7.5 Fire experiments

Fire experiments can vary from bench scale tests to full scale field tests with burning forest fuels and exposed elements of construction.

Small scale tests have the advantage of being cost effective allowing for testing of the same specimens under a range of conditions. However, full-scale field tests can be very costly and may not be able to be undertaken in severe bushfire weather conditions but do provide directly applicable results for the specific conditions of exposure.

Intermediate scale experiments with simulated bushfire exposures lie between these extremes and the AS 1530.8 standard test methods where standardised refinements of earlier fire experiments were undertaken to evaluate materials under simulated bushfire conditions.

7.6 Estimating probability of fire initiation within building when exposed to design actions

Typically, the probability of fire initiating within a building when exposed to design bushfire attack actions will be determined using quantitative risk assessment techniques (such as event trees or fault trees) in conjunction with one or more of the methods above. It is important to strike a balance by applying approaches that are practical but retain sufficient technical rigour.

The following simple hypothetical example has been used to demonstrate a practical approach. It should be noted that in many applications a broader range of design actions may be applicable but similar approaches can be adopted. The values used to estimate probabilities have been included for demonstration purposes only and should not be used for any other purpose.

Example: Estimating the probability of fire Initiation when exposed to design actions for a brick veneer house.

The building design is a brick veneer house built on a concrete slab with structural timber framing and steel roofing. A simple roof profile with gradient greater than 25° without roofing valleys was selected to reduce the risk of debris / leaf litter on the roof, together with a specification of metal leaf guards detailed to reduce the risk of ember penetration at the interface of the roof and wall. Windows and doors are aluminium framed and glazed with toughened glass. A paved path 1.2 m wide was provided around the perimeter of the house and a vegetation management plan specified.

The Verification Method requires the probability of compliant construction and maintenance of the bushfire safety plan to be estimated separately (see Chapter 8). Therefore, the estimate of the probability of fire initiation is based on assumed compliant construction at the time of the fire.

The design actions are summarised in Figure 7.1 and reflect a building more than 50 m from the expected fire front.

A review of the form of construction, design details and materials proposed was undertaken and the details were generally typical of BAL 29 construction as defined in AS 3959.

A preliminary review of the building design was undertaken in conjunction with the relevant approval authorities to identify potentially critical vulnerabilities and specific modes of attack for vulnerable features.

The results of this exercise are summarised in Table 7.2.

Figure 7.1 Derived exposure and design actions

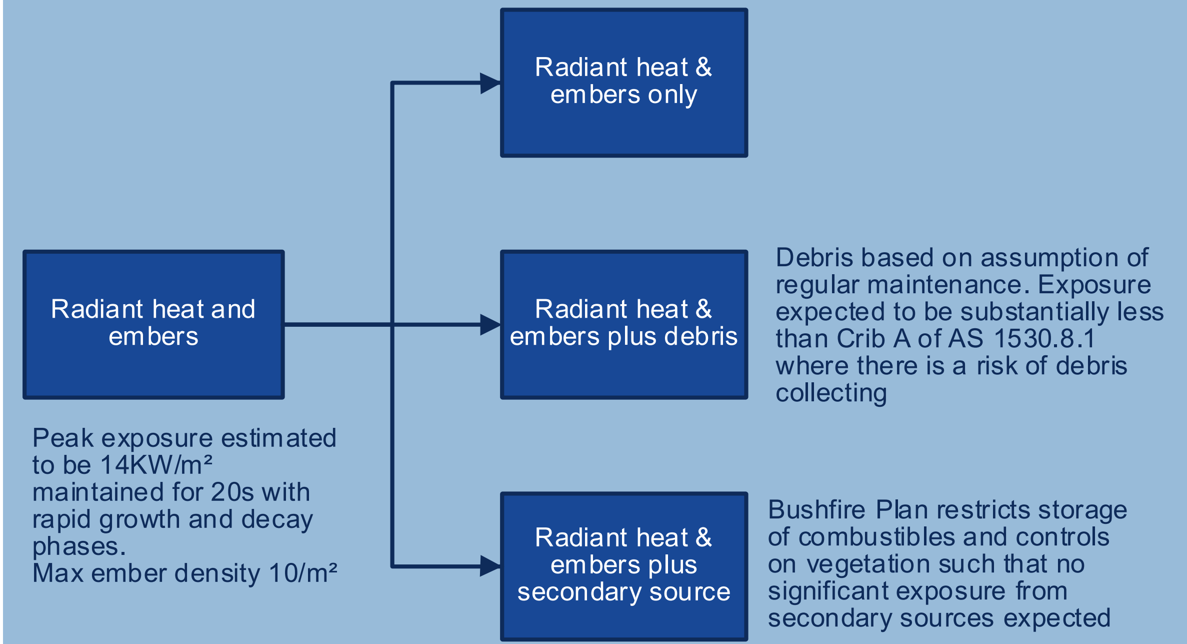


Table 7.2 Preliminary vulnerability assessment

Element / features	Details of construction	Outcome
Slab	On ground extending typically 150 mm above finished level of outside ground level	Risk of failure under expected bushfire actions very unlikely

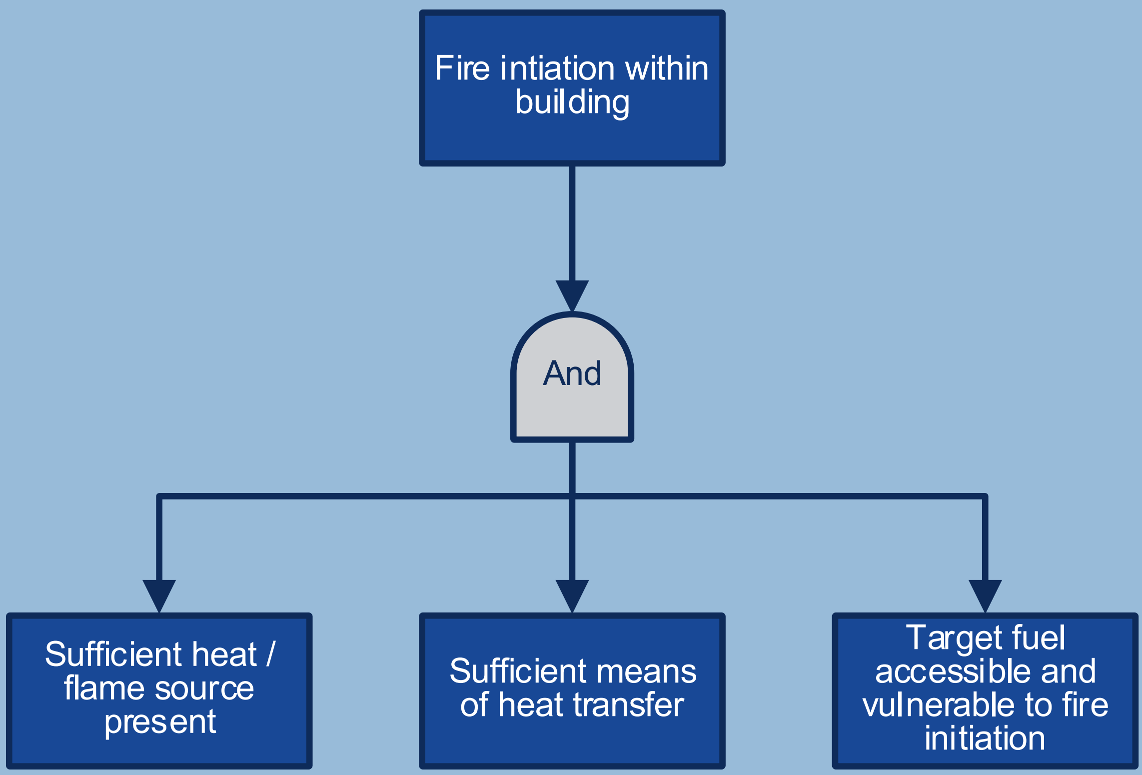
Wall	Brick veneer – 90 mm thick	Risk of failure under expected bushfire actions very unlikely
Roofing	Steel cladding	Thermally thin therefore risk of debris ignition of combustible sarking / insulation and structural frame requires consideration. Also opening up of joints in service allowing entry of embers
Large openings	Windows and doors generally BAL 29 construction and fitted with metal mesh screens	When closed, failure unlikely since standard of construction proposed substantially more resistant than exposure but there is a residual risk if exposed to debris together with risk of windows and doors being open. Specification of fly screen is basic and therefore risk of fly screen dislodgment by wind and failure needs consideration
Roof penetrations	Pipe / vents required to be metal with open ends protected by metal mesh	Effectiveness of details for ember resistance to be considered
Wall penetrations	Where practical services enter building through slab and water heating unit internal.	Effectiveness of ember resistance to be considered if penetrations are exposed
HVAC Systems	Split systems used	Penetration details for refrigerant and electrical lines to be considered
Interface between roof and walls	General protection by gutter guards	Risk of penetration requires detailed consideration
Construction /Control joints	Sealed with fire resistant sealant	Risk of sustaining combustion needs assessing
Wall Interface with doors and windows	Sealed with fire resistant sealant	Risk of sustaining combustion needs assessing

Based on the above preliminary analysis the following critical vulnerabilities were identified as requiring further analysis:

- Steel roofing
- Window and door openings
- Ember protection of service penetrations and interfaces between roof and walls and between roofing sheets
- Performance of combustible mastics.

The upper branches of a general fault tree for fire initiation are shown in Figure 7.2. This can be applied to initiation within the building, but other fault tree layouts can also be applied. Fault tree or other forms of analysis should be undertaken to estimate the probability of initiation with the each of the critical vulnerabilities exposed to the appropriate design actions and the probabilities summed to provide a total risk of fire initiation within the building when exposed to the design actions.

Figure 7.2 Upper branches of a general fault tree for fire initiation



Steel roofing

The roof profile / design and detailing has been selected to reduce the risk of collection of significant quantities of burning debris. Vegetation management plans remove the risk of overhanging trees and there are no other secondary fire exposures. Therefore, the design actions for the roof are radiant heat and ember attack.

The accessible target fuel is a sarking product with additional thermal insulation that is in contact with the steel roofing. The means of heat transfer will be generally by means of conduction and the heat / flame source is the radiant heat profile with a potential for an ember penetrating an opening in the sheet providing an additional ignition source.

Heat transfer analysis and consideration of the properties / test data of the materials indicated that fire initiation would be unlikely with 20 s exposure to a peak heat flux of 14 kW/m^2 with a large safety factor and the probability of fire initiation for compliant construction was therefore considered to be very low (<<1%).

Window and Door Openings

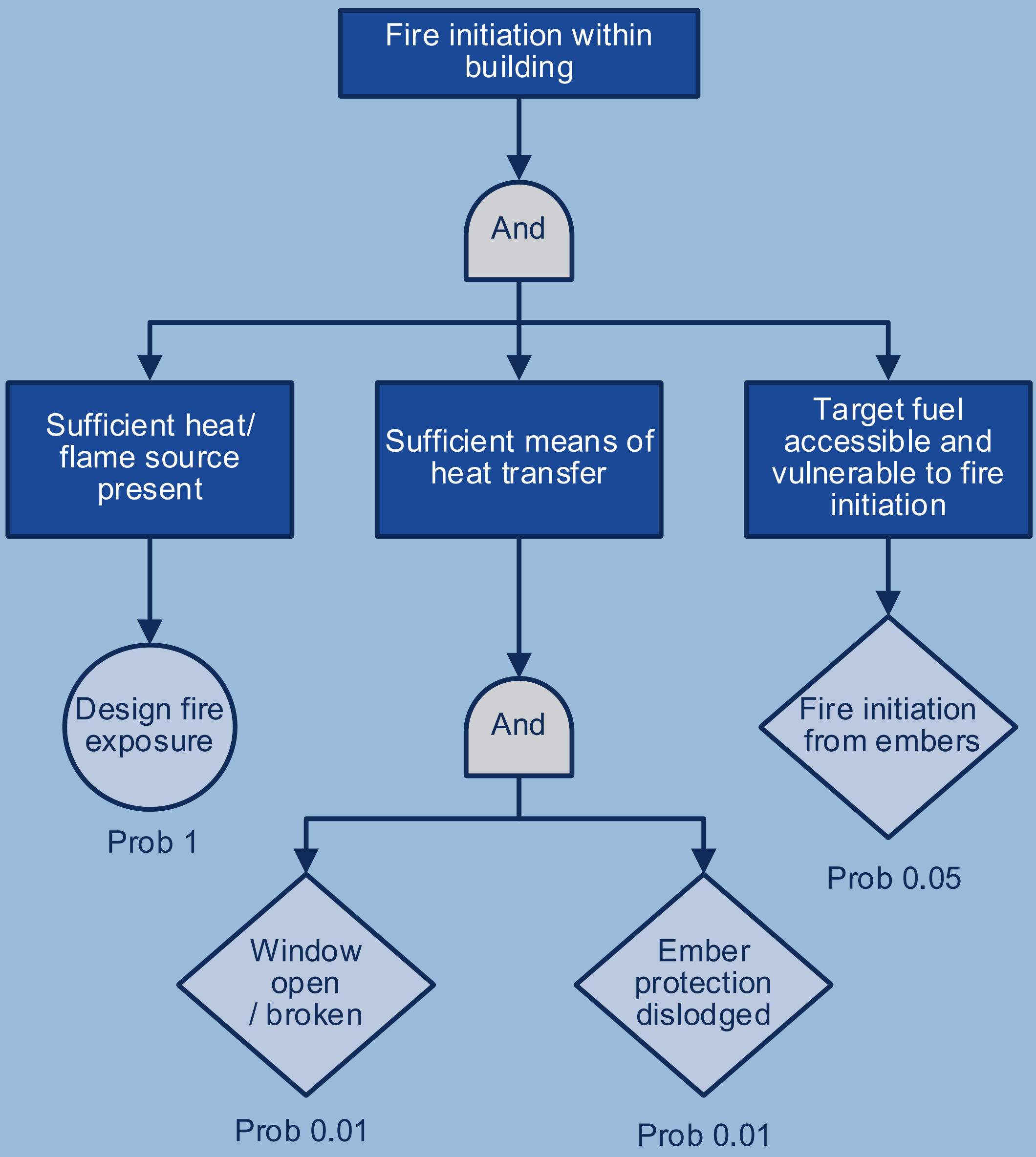
The design of windows and location of sills was such that the exposure to collections of burning debris was unlikely. For the roof, it was determined that the design action would be radiant heat and exposure to embers. Since the exposure to radiant heat is relatively low (14 kW/m^2) and of a short duration 20 s with no exposure to burning debris, based on test data and materials properties it was determined that if the window was closed the probability of internal fire initiation would be very low. The probability of fire initiation would therefore be dominated by the probability of a large opening forming, permitting entry of embers and potential ignition. The designer, peer reviewer and regulatory authorities agreed to the estimated probabilities shown in Figure 7.3 for each window opening. This yields a probability per opening under the design actions of

$$0.01 \times 0.01 \times 0.05 = 5 \times 10^{-6}.$$

The building has 30 windows therefore probability of fire initiation due to spread through any window assuming uniform exposure would be approximately

$$1.5 \times 10^{-4} \text{ (0.015\%)}$$

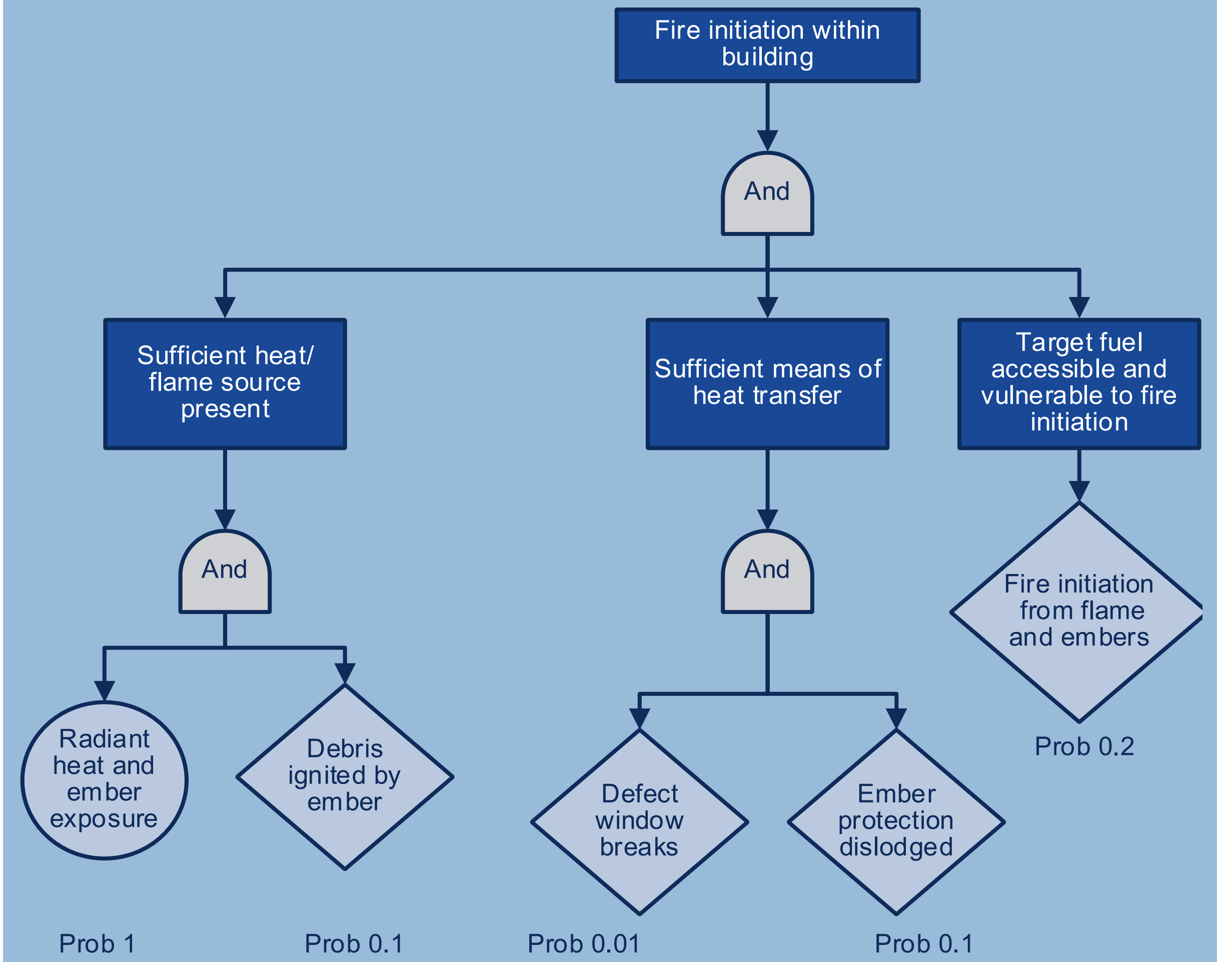
Figure 7.3 Fault tree for fire initiation due to ember entry of window opening



There is an additional risk of exposure to burning debris with respect to the door openings because of the horizontal surface at the threshold allowing collection of debris. It was determined, with the bushfire safety plan in place, debris collection at the base of the two external doors provided would present an exposure to the door less than the equivalent of an AS 1530.8.1 Type A crib. The door assembly design had previously been successfully tested and achieved a BAL 29 rating with the Type A crib and therefore the probability of failure due to expected material variations is expected to be low because of a large safety factor in relation to the magnitude and duration of the incident radiation. However, a review of the variation in material properties and modes of failure indicated that the performance of toughened glass can be sensitive to edge defects and damage to glass edges during installation and that there would be potential for the heat flux and flame exposure from burning debris to initiate failure of the glazing if a defect was present. The fault tree in Figure 7.4 shows the estimated probabilities. This yields a probability of spread through a door due to burning debris and subsequent fire initiation of approximately:

$$1 \times 0.1 \times 0.01 \times 0.1 \times 0.2 = 2 \times 10^{-5}.$$

Figure 7.4 Fault tree for Fire Initiation due to burning debris at door base



Assuming the same probability of fire initiation as windows due to embers and radiation only of 5 x 10^{-6} yields a combined probability of fire initiation from all design actions of 2.5 x 10^{-5}.

The building has 2 doors therefore probability of fire initiation due to spread through any door assuming uniform exposure would be approximately 5 x 10^{-5} (0.005%).

Ember protection of service penetrations, interfaces between roof and walls and between roofing sheets

The probability of compliance of these details with the design is assessed separately (refer Chapter 8). Due to the low ember density it was determined by the designer in conjunction with the peer reviewer and regulatory authority that the probability of fire initiation through compliant details would be very small and no further analysis was required.

Performance of combustible mastic

Experimental tests with the prescribed mastic for joint sealing had been undertaken with the mastic exposed to a radiant heat source of 15 kW/m^2 for two minutes with small ignition sources applied and there was no ignition.

Additional testing with the seals exposed to a burning debris source coincident with exposure to 15 kW/m^2 radiant heat flux was undertaken that showed that the sealant could be ignited but as the radiant heat was reduced the sealant self-extinguished and remained in place and the results were consistent for 3 trials.

It was determined by the designer in conjunction with the peer reviewer and regulatory authority that the probability of fire initiation through compliant sealant details would be very small and no further analysis was required.

Consolidation of probability of fire initiation

Based on the above analysis the probability of fire initiation from the major vulnerabilities of the facade was found to be 0.02% and since this is considerably below the 10% prescribed value for fire initiation a more detailed analysis of other vulnerabilities is not required.

The very low probability of fire initiation in the above example is expected because the façade exposure was substantially below the performance limits of the materials and construction methods specified. Generally, substantially higher probabilities of fire initiation can be expected.

8 Administration of building works, compliance and maintenance

8.1 Introduction

The general design process for GV5 and V2.7.2 is shown in Figure 2.1. Further guidance can be obtained from the International Fire Engineering Guidelines (IFEG) (2005[3]) or Quantitative Risk Assessment Guidelines, which can be applied to the design of buildings designed to resist bushfires in accordance with GV5 or V2.7.2.

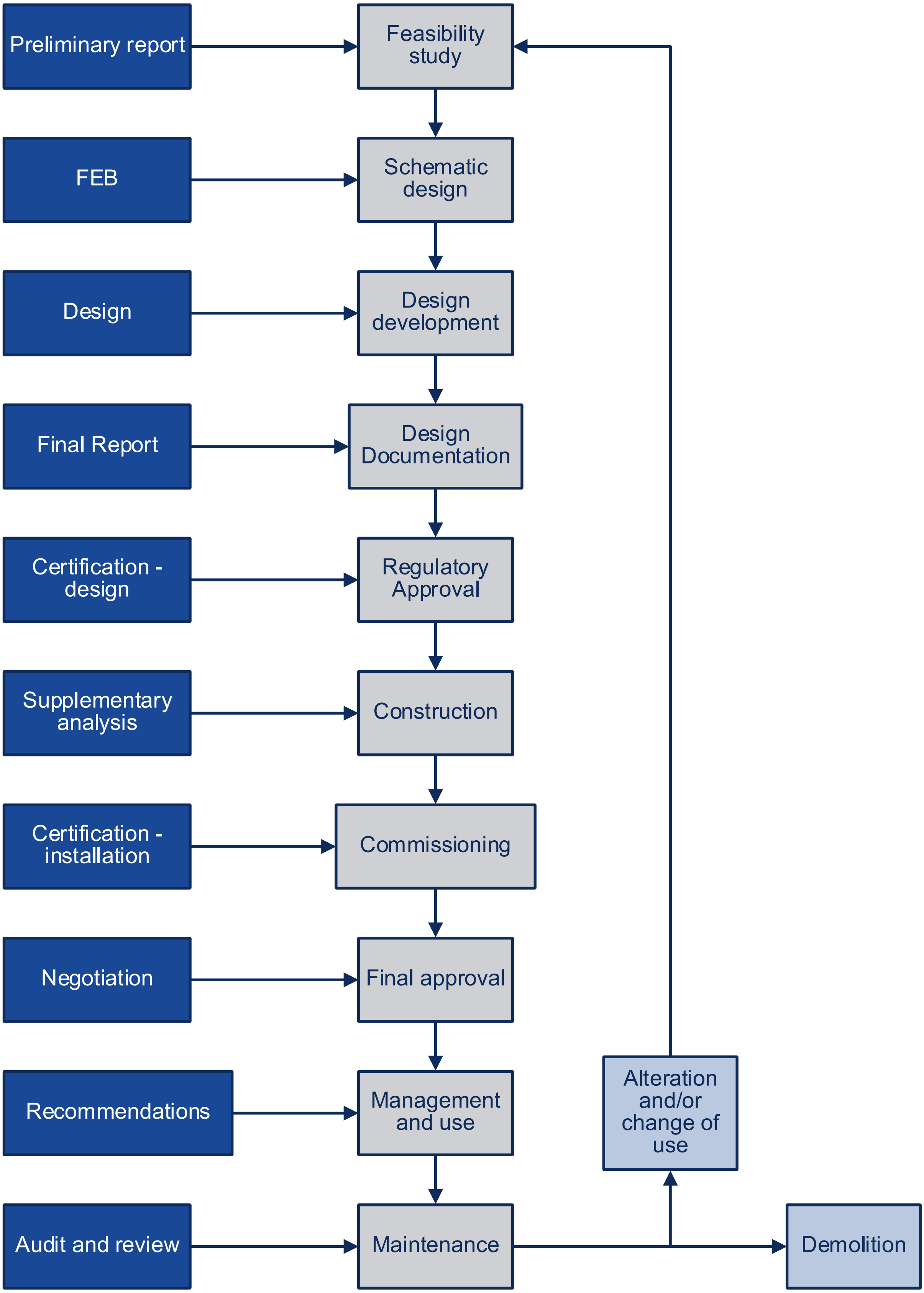
The NCC scope is limited to technical provisions and the design of buildings, with responsibility for the administration and maintenance of buildings being addressed directly by State and Territory legislation. The need for the involvement of designers and other key stakeholders with responsibility for bushfire safety through the full life-cycle of a building is important to ensure the design objectives are achieved, similar to the fire engineering design of buildings. Figure 8.1 shows the fire engineering involvement at the various stages in the life-cycle of a building based on IFEG and is also applicable to GV5 and V2.7.2.

GV5 and V2.7.2 specifically require consideration of the probability of non-complying construction of critical aspects of the approved design; and the probability of critical aspects of an approved design being fully functional during the life of the building, further highlighting the importance of compliance.

The following general guidance has been provided in relation to administration of building works, compliance and maintenance to assist in addressing the risk from non-compliant construction and inadequate maintenance. However, it should be noted that there are differences in approach between States and Territories that may require additional or different approaches to be adopted.

In addition to standard design documentation, an implementation and maintenance plan should be documented and included as a separate part of the bushfire safety plan.

Figure 8.1 Fire engineering involvement at the various stages in the life-cycle of a building from IFEG (2005[3])



The implementation and maintenance plan should include as a minimum:

- the estimated probability of non-complying construction of critical aspects of the approved design and the estimated probability of critical aspects of an approved design being fully functional during the life of the building
- the basis for the estimates of the above probabilities
- requirements for maintenance of vegetation, combustibles and other features on the relevant allotment and land adjoining the allotment
- administrative measures necessary to achieve the stated probabilities, including as appropriate:
    - an inspection regime during construction
    - inspections at completion of construction
    - inspections through the life of the building which include assessment of compliance of vegetation management and control of other fuels in accordance with the design assumptions.

Potential sources of information for determining the probability of non-complying construction and probability of critical aspects of an approved design being fully functional through the life of a building include:

- results from previous compliance audits
- review of the administration measures applicable to the specific building and generally to building and planning within the applicable State or Territory, Local Council areas
- general inspection of extent of vegetation management and building compliance within the local community.

The “accomplish by administrative action branch” of the fire safety concepts tree (Figure 4.8) is a useful tool to identify key parameters for consideration which can be incorporated in event trees for quantifying the probabilities. Typical examples are provided in Figure 8.2 and Figure 8.3.

Figure 8.2 Typical event tree for estimating probability of non-complying construction critical to performance

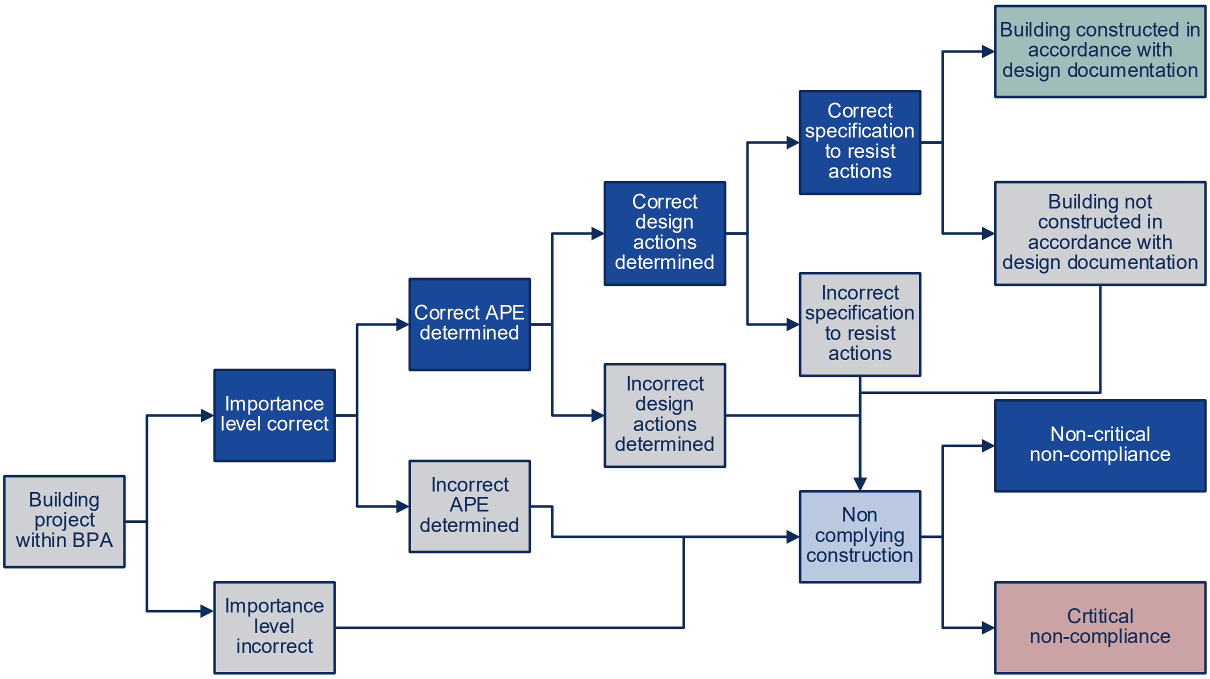
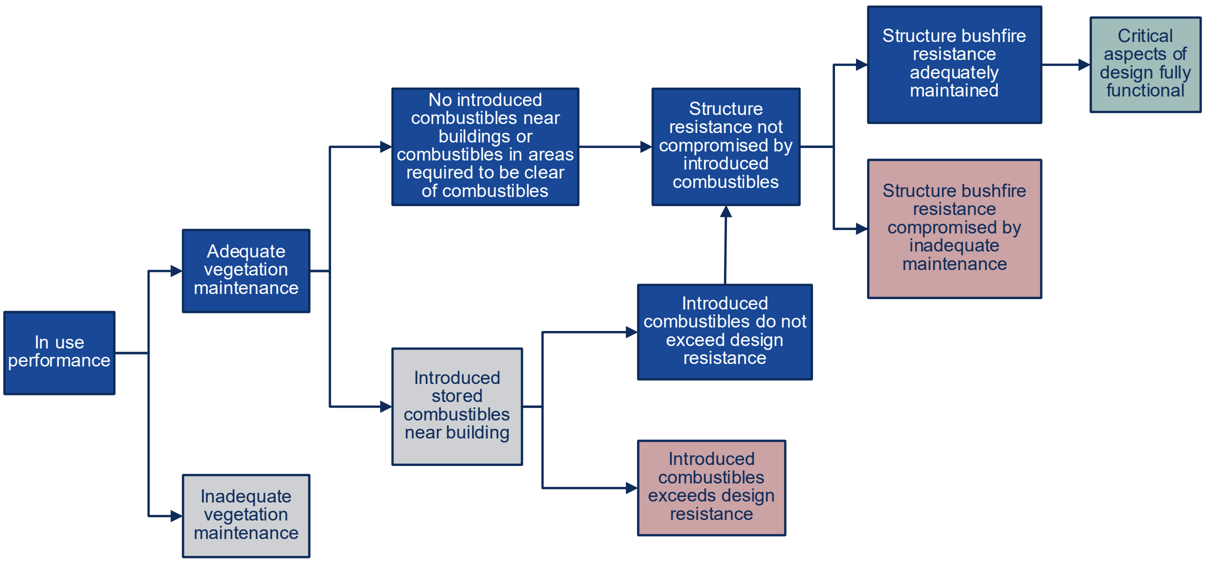


Figure 8.3 Typical event tree for estimating probability of critical aspects of an approved design being fully functional during the life of the building



Subjective judgements will be required in most instances and therefore close liaison with all relevant authorities will be necessary in determining these probabilities and inputs to event trees or fault trees used to derive the probabilities.

8.2 Bushfire safety plan

The outcome of a design undertaken in accordance with GV5 or V2.7.2 should be documented in a bushfire safety plan, which should contain all information necessary to achieve the design objectives. It should also be updated throughout the construction and commissioning, and throughout the life of the building if any conditions change. Contents should include the following:

- details of individuals and organisations with responsibility for bushfire safety design and approval
- details of the site assessment (and surrounding areas for the complex method)
- evidence of suitability demonstrating compliance with the NCC using GV5 or V2.7.2
- evidence of suitability / compliance with the bushfire safety plan for critical materials and systems used in the construction of the building
- approved construction drawings verified by the designer and approval authority
- an implementation and maintenance plan
- as built drawings verified by the builder, designer and approval authority upon completion of the building
- instructions for subsequent owners and occupiers of the expected performance of the building and maintenance requirements including controls of combustible materials
- records of audits and inspections during construction and subsequently through the life of the building.

The bushfire safety plan should be updated throughout the construction and commissioning process and complete versions provided to the approval authority(s) and the building owner.

A summary of the critical information from the bushfire safety plan explaining the fire safety strategy and requirements for the maintenance of vegetation, combustible materials and building fire safety features should be prepared and a copy provided in the electrical supply enclosure or similar readily accessible but secure location for building occupants.

9 References

1.

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APPENDICES

Appendix A Compliance with the NCC

A.1 Responsibilities for regulation of building and plumbing in Australia

Under the Australian Constitution, State and Territory governments are responsible for regulation of building, plumbing and development / planning in their respective State or Territory.

The NCC is an initiative of the Council of Australian Governments and is produced and maintained by the ABCB on behalf of the Australian Government and each State and Territory government. The NCC provides a uniform set of technical provisions for the design and construction of buildings and other structures, and plumbing and drainage systems throughout Australia. It allows for variations in climate and geological or geographic conditions.

The NCC is given legal effect by building and plumbing regulatory legislation in each State and Territory. This legislation consists of an Act of Parliament and subordinate legislation (e.g. Building Regulations) which empowers the regulation of certain aspects of buildings and structures, and contains the administrative provisions necessary to give effect to the legislation.

Each State's and Territory's legislation adopts the NCC subject to the variation or deletion of some of its provisions, or the addition of extra provisions. These variations, deletions and additions are generally signposted within the relevant section of the NCC, and located within appendices to the NCC. Notwithstanding this, any provision of the NCC may be overridden by, or subject to, State or Territory legislation. The NCC must therefore be read in conjunction with that legislation.

A.2 Demonstrating compliance with the NCC

Compliance with the NCC is achieved by complying with the Governing Requirements of the NCC and relevant Performance Requirements.

The Governing Requirements are a set of governing rules outlining how the NCC must be used and the process that must be followed.

The Performance Requirements prescribe the minimum necessary requirements for buildings, building elements, and plumbing and drainage systems. They must be met to demonstrate compliance with the NCC.

Three options are available to demonstrate compliance with the Performance Requirements:

- a Performance Solution,
- a DTS Solution, or
- a combination of a Performance Solution and a DTS Solution.

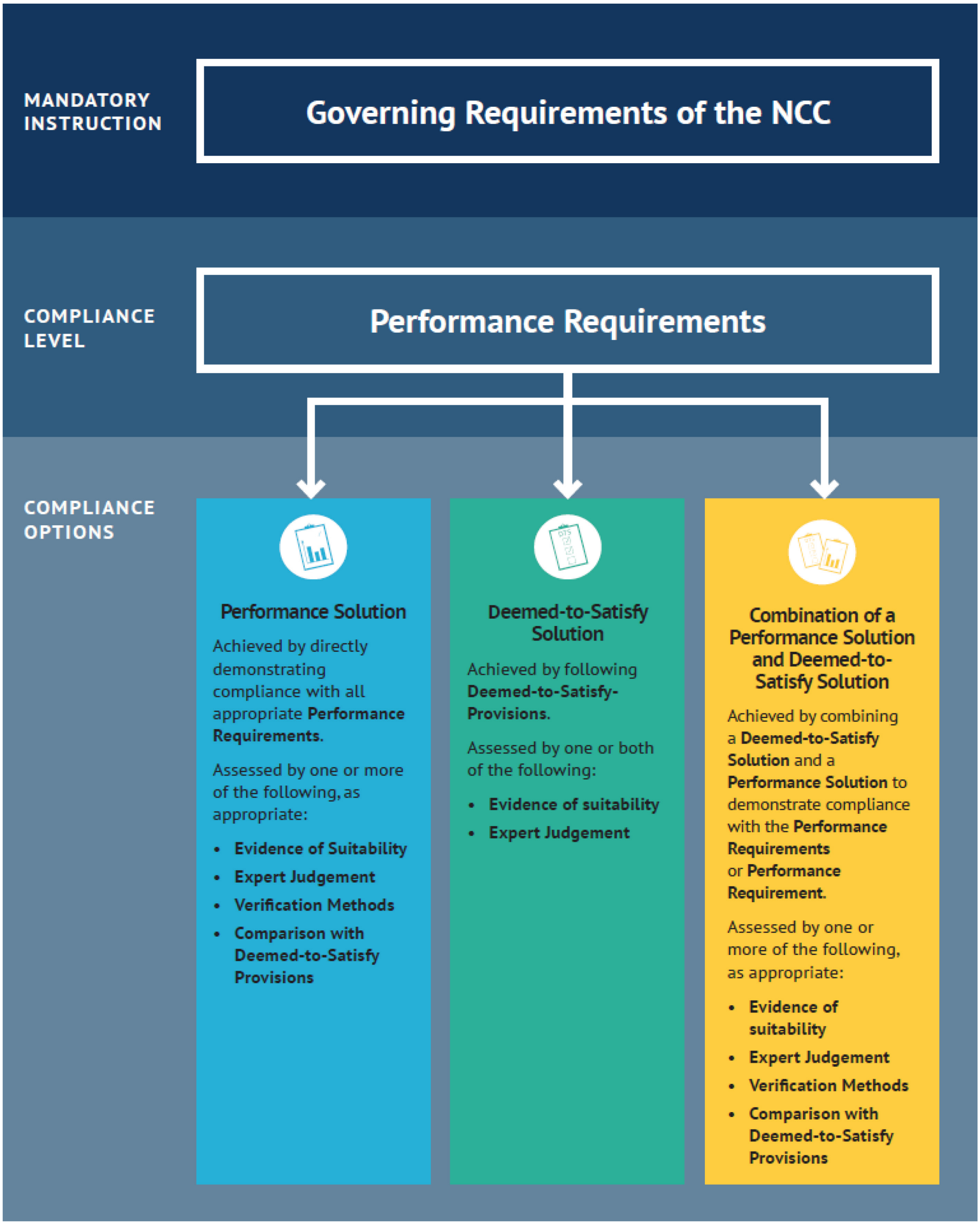
All compliance options must be assessed using one or a combination of the following Assessment Methods, as appropriate:

- Evidence of Suitability
- Expert Judgement
- Verification Methods
- Comparison with DTS Provisions.

A figure showing hierarchy of the NCC and its compliance options is provided in Figure A.1. It should be read in conjunction with the NCC.

To access the NCC or for further general information regarding demonstrating compliance with the NCC visit the ABCB website (abcb.gov.au).

Figure A.1 Demonstrating compliance with the NCC



Appendix B Acronyms

The following table, Table B.1 contains acronyms used in this document.

Table B.1 Acronyms

Acronym	Meaning
ABCB	Australian Building Codes Board
APE	Annual Probability of Exceedance
AS	Australian Standard
AS/NZS	Australian Standard / New Zealand Standard
BAL	Bushfire Attack Levels
BCA	Building Code of Australia
COAG	Council of Australian Governments
DTS	Deemed-to-Satisfy
Handbook	Except in the Preface, means this Handbook
HVAC	Heating, Ventilation and Air-Conditioning
IFEG	International Fire Engineering Guidelines
IGA	Inter-government agreement
NCC	National Construction Code
NSW	New South Wales
QRA	Quantitative Risk Assessment
VM	Verification Method

Appendix C Defined terms

C.1 NCC defined terms

NCC definitions for the terms used in this handbook can be found in:

- Schedule 3, NCC 2019 Volumes One, Two and Three.

C.2 Other terms

Fire weather is typically expressed through some combination of surface air temperature, precipitation, relative humidity and wind speed. These meteorological variables are commonly combined into a single index using empirical relationships such as the McArthur Forest Fire Danger Index or the Grassland Fire Danger Index.

Hazard is a condition that has the potential to cause injury, damage or loss.

Risk is a measure of human injury (harm), environmental damage or economic loss in terms of incident likelihood and the magnitude of injury, damage or loss.

Subject building(s) means the building or group of buildings that are the subject of analysis to ascertain their compliance with the NCC.

Topography is the land configuration including its relief and the position of its natural and man-made features.