National Construction Code

Bushfire Verification Methods

Handbook

Australian Building Codes Board

The Australian Building Codes Board

The Australian Building Codes Board (ABCB) is a standards writing body responsible for the National Construction Code (NCC), WaterMark and CodeMark Certification Schemes.

The ABCB is a joint initiative of all levels of government in Australia, together with the building and plumbing industry. Its mission is to oversee issues relating to health, safety, amenity, accessibility and sustainability in building.

For more information visit the ABCB website.

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Preface

This handbook is one of a series by the ABCB. Handbooks expand on areas of existing regulation or relate to topics that are not regulated by the NCC. They provide advice and guidance.

The Bushfire Verification Methods handbook assists in understanding the Verification Methods for building in bushfire prone areas in NCC Volumes One and Two (G5V1 in NCC Volume One and H7V2 in NCC Volume Two).

It addresses issues in generic terms and is not a document that sets out specific compliance advice for developing solutions to comply with the requirements in the NCC. It is expected that this handbook guides readers to develop solutions relevant to specific situations in accordance with the generic principles and criteria contained herein.

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Reminder

This handbook is not mandatory or regulatory in nature. 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 NCC and 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.

This handbook has been developed to provide guidance to practitioners seeking to demonstrate compliance with the Performance Requirements for construction in bushfire prone areas in NCC Volumes One and Two, using an NCC Verification Method.

The handbook 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.

1.1 Scope

This handbook's scope relates to Bushfire Verification Methods G5V1 and H7V2 which are optional Assessment Methods that can be used to demonstrate compliance with the relevant NCC Performance Requirements.

The building classifications to which the NCC applies bushfire related Performance Requirements are:

- (a) a Class 1, 2 or 3 buildings; and
- (b) a Class 9a health-care building; and
- (c) a Class 9b—
  - (i) early childhood centre; and
  - (ii) primary or secondary school; and
- (d) a Class 9c residential care building; and
- (e) a Class 10a building or deck immediately adjacent or connected to a building of a type listed in (a) to (d).

Alerts

(1) Verification Method G5V1 does not apply to a Class 9 building, which means it doesn't apply to a Class 9a, Class 9b or Class 9c building.

Alerts

(2) Bushfire mitigation requirements for additional building classifications may be nominated as a state or territory variation in the appropriate State or Territory Schedule of the NCC or nominated in specific State and Territory Regulations.

1.2 Design and approval of Performance Solutions

The design and approval processes of Performance Solutions for the construction of buildings in bushfire prone areas is expected to be like that adopted for demonstrating compliance using other NCC Performance Solutions. Since the approval process for Performance Solutions varies between the responsible state and territory governments, it is likely to also be the case with designs incorporating construction for bushfire-prone areas and requirements should be checked for the relevant jurisdiction.

Notwithstanding the quantified input and acceptance criteria, other qualitative aspects of design are discussed in this handbook that require consideration throughout the design and approval process.

An appropriately qualified person should be engaged to undertake an assessment and analysis using Verification Methods G5V1 or H7V2 and may be aided by the early and significant involvement from regulatory and/or fire authorities, peer reviewer(s) and/or a technical panel as appropriate to the relevant jurisdiction.

1.3 Using this document

Abbreviations used in this document are in Appendix A.

General information about complying with the NCC and responsibilities for building and plumbing regulation is in Appendix B.

Additional information about losses from Australian bushfires is in Appendix C.

Defined terms used in this handbook are in Appendix D.

Further reading and references are in Appendix E.

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

NCC extracts[1]

Examples

Alerts or Reminders

1.4 Data limitations

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

1.5 Other ABCB documents

Class 10c buildings (private bushfire shelters) are required to comply with Performance Requirement H7P6 which lies outside the scope of Verification Methods G5V1 and H7V2

Although some content from this document may be relevant, specific guidance with respect to Class 10c buildings is in the ABCB Design and Construction of Private Bushfire Shelters Performance Standard, which is available from the ABCB website.

[1] NCC extracts italicise defined terms as per the NCC. See Schedule 1 of the NCC for further information.

2 Performance Requirements and compliance options

2.1 NCC Volume One

Performance Requirement G5P1 in NCC Volume One applies to Class 2 and 3 buildings, certain Class 9 buildings housing vulnerable occupants, and associated Class 10a buildings and decks. An excerpt of G5P1 is shown below.

G5P1 Bushfire resistance

A building that is constructed in a *designated bushfire prone area* must be designed and constructed to—

(a) reduce the risk of ignition from a *design bushfire* with an annual exceedance probability not more than 1:100 years, or 1:200 years for a Class 9 building; and

(b) take account of the assessed duration and intensity of the *fire actions* of the *design bushfire*; and

(c) be designed to prevent internal ignition of the building and its contents; and

(d) maintain the structural integrity of the building for the duration of the *design bushfire*.

Applications:

G5P1 applies in a *designated bushfire prone area* to—

(a) a Class 2 or 3 building; and

(b) a Class 9a *health-care building*;

(c) and a Class 9b—

- (i) *early childhood centre*; and
- (ii) primary or secondary *school*; and

(d) a Class 9c *residential care building*; and

(e) a Class 10a building or deck immediately adjacent or connected to a building of a type listed in (a) to (d).

Performance Requirement G5P2 specifies additional bushfire requirements for certain Class 9 buildings housing vulnerable occupants. An excerpt of G5P2 is shown below.

G5P2 Additional bushfire requirements for certain Class 9 buildings

A building that is constructed in a *designated bushfire prone area* and occupied by people who may be unable to readily evacuate the building prior to a bushfire must, to the degree necessary—

(a) reduce the risk of an untenable indoor environment for occupants during a bushfire event, appropriate to the—
  (i) location of the building relative to fire hazards, including—
    (A) classified vegetation; and
    (B) adjacent buildings, structures and movable objects; and
    (C) carparking areas and allotment boundaries; and
    (D) other *combustible* materials; and
  (ii) number of occupants to be accommodated within the building; and
  (iii) intensity of bushfire attack on the building; and
  (iv) duration of occupancy; and
  (v) intensity of potential consequential fires; and
  (vi) occupant tenability within the building before, during and after the bushfire event; and
  (vii) combined effects of structural, fire exposure and other effects to which the building may reasonably be subjected; and
  (viii) provision of firefighting equipment and water supply to facilitate protection of the building; and
(b) be provided with vehicular access to the *site* to enable firefighting and emergency personnel to defend or evacuate the building; and
(c) have access to a sufficient supply of water for firefighting purposes on the *site*; and
(d) provide safe access within the *site* to the building (including carparking areas), as well as safe egress after the bushfire event.

Applications

G5P2 applies to the following buildings located in a *designated bushfire prone area*—

(a) a Class 9a *health-care building*; and

(b) a Class 9b—

(i) *early childhood centre*; and

(ii) primary or secondary *school*; and

(c) a Class 9c *residential care building*.

Notes

G5P2 does not guarantee the safety of building occupants or the maintenance of tenable conditions within a building during a bushfire event.

To help apply Performance Requirements the NCC also provides a corresponding Objective and Functional Statement.

For construction in bushfire prone areas, the relevant Objective and Functional Statements are G5O1 and G5F1. Excerpts of G5O1 and G5F1 are shown below:

G5O1 Objective

The Objective of this Part is to—

(a) safeguard occupants from injury from the effects of a bushfire; and

(b) protect buildings from the effects of a bushfire; and

(c) facilitate temporary shelter for building occupants who may be unable to readily evacuate the building prior to a bushfire.

Applications

(1) G5O1(a) and (b) apply in a *designated bushfire prone area* to—

(a) a Class 2 or 3 building; or

(b) a Class 10a building or deck associated with a Class 2 or 3 building.

(2) G5O1(a), (b) and (c) apply in a *designated bushfire prone area* to—

(a) a Class 9a *health-care building*; and

Applications

- (b) a Class 9b—
  - (i) *early childhood centre*; and
  - (ii) primary or secondary *school*; and
- (c) a Class 9c *residential care building*; and
- (d) a Class 10a building or deck immediately adjacent or connected to a building of a type listed in (a) to (c).

G5F1 Construction in bushfire prone areas

A building constructed in a *designated bushfire prone area*—

- (a) is to provide a resistance to bushfires in order to reduce the danger to life and minimise the risk of the loss of the building; and
- (b) if occupied by people who may be unable to readily evacuate the building prior to a bushfire, is to be constructed so as to provide its occupants shelter from the direct and indirect actions of a bushfire.

Applications

(1) G5F1(a) applies in a *designated bushfire prone area* to—

- (a) a Class 2 or 3 building; or
- (b) a Class 10a building or deck associated with a Class 2 or 3 building; or
- (c) a Class 10a building or deck immediately adjacent or connected to a building of a type listed in (2)(a), (b) or (c).

(2) G5F1(a), and (b) apply in a *designated bushfire prone area* to—

- (a) a Class 9a *health-care building*; and
- (b) a Class 9b—
  - (i) *early childhood centre*; and
  - (ii) primary or secondary *school*; and
- (c) a Class 9c *residential care building*.

The Objective and Functional Statement acknowledge it is not possible to totally eradicate the risk to life and property from buildings in bushfire prone areas. They indicate the NCC provisions are to reduce the danger to life and the risk of building loss.

The Objective and Functional Statement also identify the need for a building housing vulnerable occupants to provide shelter in recognition of the difficulties and hazards associated with evacuating vulnerable people. A note is provided in Performance Requirement G5P2 to explain there is no guarantee for the safety of building occupants or the maintenance of tenable conditions within a building during a bushfire event. This is in recognition that it is not possible to completely remove all risks associated with bushfire. Sheltering in buildings should, therefore, only be undertaken as a last resort when evacuation is no longer possible.

2.2 NCC Volume Two

Performance Requirement H7P5 in NCC Volume Two is applicable to Class 1 buildings and associated Class 10a buildings and decks. An excerpt of H7P5 is shown below.

H7P5 Buildings in bushfire prone areas

A Class 1 building or a Class 10a building or deck associated with a Class 1 building that is constructed in a *designated bushfire prone area* must be designed and constructed to—

(a) reduce the risk of ignition from a *design bushfire* with an annual exceedance probability not more than 1:50 years; and

(b) take account of the assessed duration and intensity of the *fire actions* of the *design bushfire*; and

(c) be designed to prevent internal ignition of the building and its contents; and

(d) maintain the structural integrity of the building for the duration of the *design bushfire*.

A design bushfire is defined in the NCC as the characteristics of a bushfire, its ignition, spread and development, which arises from weather conditions, topography and fuel (vegetation) in a given setting, used to determine fire actions.

To help apply Performance Requirements, the NCC also provides a corresponding Objective (H7O1 (e) and (f)) and Functional Statement (H7F4). Excerpts of H7O1 and H7F4 are shown below.

H7O1

The Objective is to—

…

(e) protect a building from the effects of a bushfire; and

(f) reduce the likelihood of fatalities arising from occupants of a Class 1a dwelling not evacuating a property prior to exposure from a bushfire event.

Applications:

…

H7O1(f) only applies to a Class 10c building.

H7F4 Bushfire areas

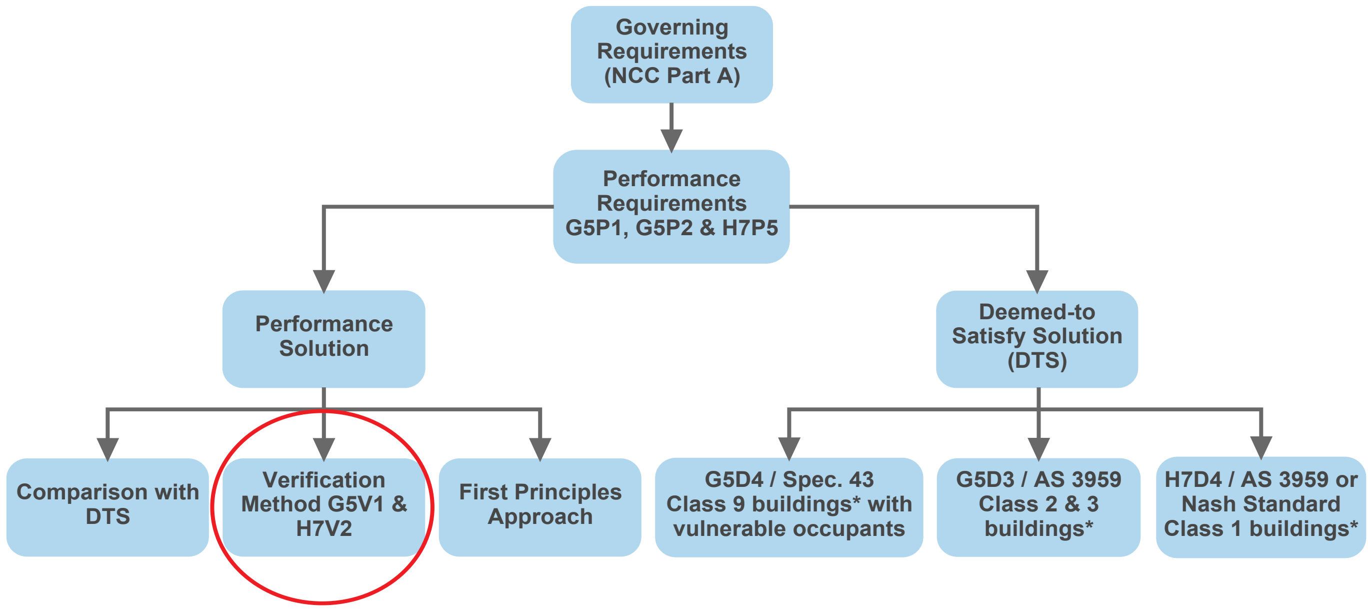
A Class 1 building or a Class 10a building or deck associated with a Class 1 building constructed in a *designated bushfire prone area* is to provide resistance to bushfires in order to reduce the danger to life and reduce the risk of the loss of the building.

The Objective and Functional Statement acknowledge it is not possible to totally eradicate the risk to property and life from buildings in bushfire prone areas and indicate the NCC provisions aim to reduce the danger to life and the risk of building loss.

2.3 Compliance options

The various options for demonstrating compliance with the relevant bushfire Performance Requirements are shown in Figure 2.1.

Figure 2.1 Compliance options for buildings in designated bushfire prone areas



* Construction requirements also apply to associated Class 10 buildings and decks

A Performance Solution for the construction of buildings in bushfire prone areas follows a similar process to other Performance Solutions. This is described in the Performance Solution Process Handbook (ABCB 2021). However, administrative processes relating to design and approval of Performance Solutions varies between the responsible state and territory governments and therefore the required administrative processes and applicable legislation should be checked with the relevant jurisdiction.

Performance Requirements G5P1, G5P2 and H7P5 apply to certain buildings in designated bushfire prone areas. If a Performance Solution is adopted, compliance can be demonstrated by Comparison with the Deemed-to-Satisfy (DTS) Provisions, a first principles approach or a Verification Method. The bushfire Verification Methods contained in the NCC are the subject of this handbook and highlighted by the circle with a red border in Figure 2.1.

The bushfire Verification Methods include some quantification of the Performance Requirements for construction in bushfire prone areas. Notwithstanding the quantified input and acceptance criteria, other qualitative aspects of Performance Solutions for construction in bushfire prone areas, require assessment and analysis throughout the design and approval process.

For buildings in bushfire prone areas, compliance via a DTS Solution is achieved by applying prescribed rules which are commonly laid out in standards or schedules. For Class 1, 2 and 3 buildings in bushfire prone areas Australian Standard AS 3959-2018 (Standards Australia 2018c) or other nominated standards apply. For Class 9 buildings housing vulnerable people NCC Volume One Specification 43 applies (Refer Figure 2.1). More information on complying with the NCC can be found in Appendix B.

Further reading on this topic can be found in the references listed in Appendix E of this document.

3 Verification Methods

3.1 Introduction and application

There are 2 Bushfire Verification Methods:

(1) G5V1 in NCC Volume One

(2) H7V2 in NCC Volume Two.

They adopt the same approach.

Verification Method G5V1 is used to demonstrate compliance with Performance Requirement G5P1 in NCC Volume One. Refer to the NCC or Section 3.3 of this handbook for an excerpt of G5V1 from NCC Volume One.

Verification Method H7V2 is used to demonstrate compliance with Performance Requirement H7P5 in NCC Volume Two. Refer to the NCC or Section 3.4 of this handbook for an excerpt of H7V2 from NCC Volume Two.

Alert

Verification Method G5V1 does not apply to Class 9 buildings, which means it doesn't apply to a Class 9a, Class 9b or Class 9c building.

In addition to G5P1, Class 9 buildings are also required to comply with Performance Requirements G5P2. A DTS Solution or a Performance Solution with supporting evidence of suitability to demonstrate compliance with G5P1 and G5P2 is required for Class 9 buildings.

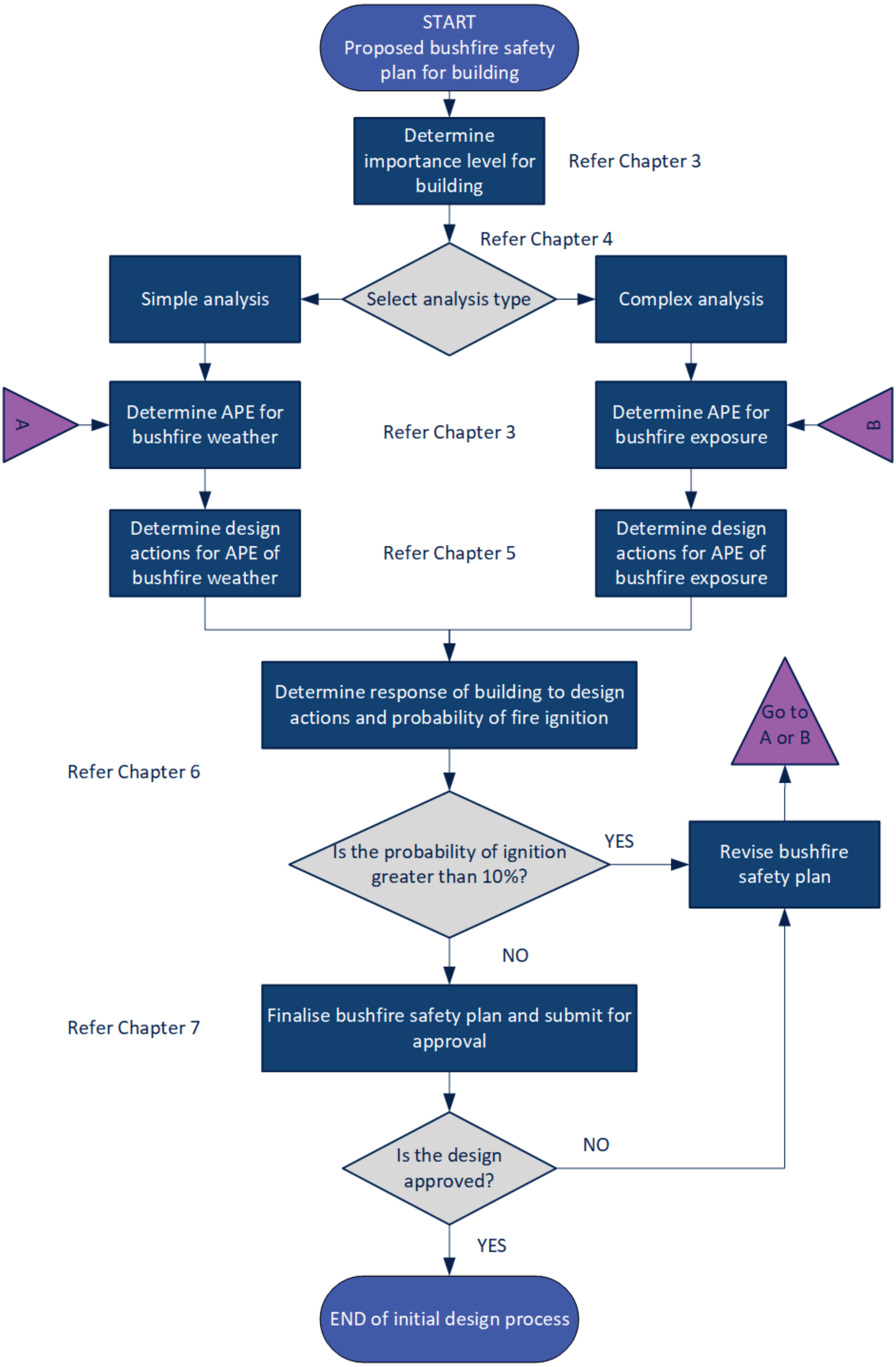
3.2 Process

The flowchart at Figure 3.1 shows the processes to be followed when using Verification Methods G5V1 or H7V2 and refers to the relevant chapter or sections of this document for further guidance.

The process for determining the Importance Level of a building or structure is described in Section 3.5.5.

Section 3.5.6 describes the process for determining the prescribed Annual Probability of Exceedance (APE).

Figure 3.1 Verification Methods G5V1 and H7V2 flowchart



The process for the selection of the type of analysis is described in Chapter 4.

There are 2 types of analysis defined in G5V1 and H7V2.

(1) A **simple** method that can be applied to a particular site based on the vegetation and topography surrounding the building with the prescribed APE expressed in terms of fire weather (weather conditions). From these design weather conditions, vegetation and topography, relevant bushfire design fires can be defined.

(2) 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 options for the determination of design actions.

Chapter 6 describes options for the determination of the response of elements of construction to bushfire attack and the probability of fire ignition.

Chapter 7 relates primarily to implementation and maintenance of provisions but includes information relating to the development of a bushfire safety plan.

3.3 Verification Method G5V1

Verification Method G5V1 in NCC Volume One is shown below.

G5V1 Buildings in bushfire prone areas

(1) Compliance with *Performance Requirement* G5P1 is verified if the ignition probability for a building exposed to a *design bushfire* does not exceed 10%.

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

(a) assigning the building or structure with an Importance Level in accordance with (3); and

(b) determining the corresponding annual probability of exceedance in accordance with Table G5V1.

(3) A building or structure's Importance Level must be identified as one of the following:

G5V1 Buildings in bushfire prone areas

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

(b) 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.

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

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

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

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

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

(d) Importance Level 4 — where the building or structure is—

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

(ii) associated with hazardous facilities; or

(iii) subject to a necessary ‘defend in place’ strategy and is a—

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

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

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

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

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

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

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

(i) Direct attack from airborne burning embers.

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

(iii) Radiant heat from a bushfire front.

(iv) Direct flame attack from a bushfire front.

G5V1 Buildings in bushfire prone areas

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

(a) fire weather; and

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

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

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

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

(f) effective size of fire front; and

(g) duration of exposure; and

(h) flame height; and

(i) flame tilt; and

(j) flame adhesion to sloping land; and

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

(6) The assessment process must include consideration of—

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

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

(c) inclusion of safety factors; and

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

Limitations:

G5V1 does not apply to a Class 9 building.

Notes:

For a building that is subject to G5P2, and therefore outside the scope of G5V1, the building would need to comply with either—

(a) *Performance Requirement* G5P2 by means of a *Performance Solution*; or

Notes:

(b) the Deemed-to-Satisfy Provisions of G5D4 if the building is located in an area subject to a Bushfire Attack Level (BAL) not exceeding BAL – 12.5.

Table G5V1 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

Table Notes

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.

3.4 Verification Method H7V2

Verification Method H7V2 in NCC Volume Two is shown below:

H7V2 Buildings in bushfire prone areas

(1) Compliance with H7P5 is verified if the ignition probability for a building exposed to a *design bushfire* does not exceed 10%.

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

(a) assigning the building or structure with an Importance Level in accordance with (3); and

(b) determining the corresponding annual probability of exceedance in accordance with Table H7V2.

(3) A building or structure's Importance Level must be identified as one of the following:

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

H7V2 Buildings in bushfire prone areas

(b) 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.

(c) Importance Level 4 — where the building is a Class 10c building and is subject to a necessary 'defend in place' strategy.

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

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

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

(i) Direct attack from airborne burning embers.

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

(iii) Radiant heat from a bushfire front.

(iv) Direct flame attack from a bushfire front.

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

(a) fire weather; and

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

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

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

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

(f) effective size of fire front; and

(g) duration of exposure; and

(h) flame height; and

(i) flame tilt; and

(j) flame adhesion to sloping land; and

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

(6) The assessment process must include consideration of—

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

H7V2 Buildings in bushfire prone areas

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

(c) inclusion of safety factors; and

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

Explanatory information:

NCC Volume Two does not apply to buildings that are Importance Level 3, therefore this Importance Level is not included under (3).

Table H7V2 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

Table Notes

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.

3.5 Critical interpretations

3.5.1 Approach to interpretation

When demonstrating compliance with the NCC, compliance with Performance Requirements is mandatory and the associated Objectives and Functional Statements provide supplementary guidance to help interpret the Performance Requirements.

It is therefore appropriate to use the Objective and Functional Statements to inform the general interpretation of the performance criteria. To assist interpreting any terms used to quantify Performance Requirements, the following standards could be used:

- AS 3959-2018 Construction of Buildings in Bushfire-Prone Areas (Standards Australia 2018)

- AS 1530.8.1-2018 Methods for fire tests on building materials, components and structures – Part 8.1: Tests on elements of construction for buildings exposed to simulated bushfire attack - Radiant heat and small flaming sources (Standards Australia 2018a)
- AS 1530.8.2-2018 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 2018b).

Refer to Chapter 2 for the relevant Performance Requirements, Objectives and Functional Statements for NCC Volumes One and Two.

3.5.2 Interpretation of ignition

The Performance Requirements state that the risk of ignition must be reduced, with the quantified metric in the Verification Methods, "if the ignition probability for a building exposed to a design bushfire does not exceed 10%".

The term ignition is in common usage and general definitions for fire safety engineering and testing purposes include ignition of sustained combustion. However, the period of sustained combustion permitted, type of combustion (flaming or smouldering or glowing) together with the extent and location of materials undergoing combustion require further qualification and quantification.

Performance Requirements G5P1 and H7P5 include requirements for buildings to:

- reduce the risk of ignition from a design bushfire
- be designed to prevent internal ignition of the building and its contents.

A review of the Objective and Functional Statements shows a focus on providing sufficient protection of a building to reduce the risk to life and reduce the risk of building loss.

Therefore, 'ignition' for the purpose of G5V1 and H7V2 is considered as the occurrence of sustained combustion or fire ignition within the building. This clarifies that ignition of parts of the external facade of a building is permitted provided that flaming combustion is not sustained to the extent that the evacuation of occupants is compromised, or fire spread to the building interior occurs.

This is consistent with AS 3959-2018, AS 1530.8.1-2018 and AS 1530.8.2-2018, referenced in the DTS Provisions. These standards specify criteria listed in Table 3.1.

Since the overarching approach to quantifying Performance Requirements and developing associated Verification Methods are policy neutral, it is appropriate to apply the criteria from Table 3.1 when defining ignition of a building and protection of evacuation paths.

Table 3.1 AS 1530.8-2018 criteria for prevention of ignition of a building

Category	Scenario description	Criteria	Timing
Ignition within building	Ember entry through gaps and openings	Gap from the fire exposed face to the non-exposed face through which a 3 mm diameter probe can penetrate	Applies throughout exposure to bushfire action and for 60 minutes from the start of exposure
Ignition within building	Flaming within building	Sustained flaming for more than 10 s on the non-fire side	Applies throughout exposure to bushfire action and for 60 minutes from the start of exposure
Sustained flaming of external surfaces with potential risk of internal spread	Prolonged flaming combustion on external facade	Flaming combustion on the fire exposed face after 60 minutes from the start of exposure – risk of continuing spread to building interior	Applies at end of 60 minute test
Ignition within building	Internal fire spread due to radiant heat	Radiant heat flux of 15 kW/m^2 365 mm from non-fire exposed face	Applies throughout exposure to bushfire action and for 60 minutes from the start of the exposure
Ignition within building	Conduction of heat through walls (insulation failure)	Mean and maximum temperature rises greater than 140K and 180K respectively on non-fire side	Applies throughout exposure to bushfire action and for 60 minutes from the start of the exposure
Protection of evacuation paths	Obstruction of evacuation path due to heat flux	Radiant heat flux from fire exposed face exceeds 3 kW/m^2 250 mm from fire exposed face	Applies 20 to 60 minutes after the start of the exposure

Category	Scenario description	Criteria	Timing
Incipient spread potentially leading to ignition within building	Temperatures within external façade initiate incipient spread of fire	Mean and maximum temperature exceeding 250°C and 300°C respectively	Applies 20 to 60 minutes after start of exposure

Whilst the emphasis is on internal ignition or conditions likely to lead to internal ignition, the AS 1530.8 series also requires the assessment of structural adequacy where appropriate. This addresses the part of the Performance Requirement that requires the structural integrity of the building for the duration of the design bushfire is maintained. This is relevant to the protection of evacuation paths attached to the building and interactions between elements of construction.

3.5.3 Interpretation of fire actions

The NCC definition of fire action is outlined below.

Fire actions means each of the following:

(a) airborne embers;

(b) burning debris and/or accumulated embers adjacent to building elements;

(c) heat transfer from combustible materials within the site;

(d) radiant heat from a bushfire front;

(e) flame contact from a bushfire front;

(f) the period of time post fire front subject to collapsing vegetation due to persistent combustion.

In relation to item (c) it is important to note that the NCC defines the term 'site' as "the part of the allotment of land on which a building stands or is to be erected."

Therefore, this requirement only applies to the subject building, attached structures with a common roof space and garages and carports below the subject building and decks attached to the building. AS 3959-2018 applies additional requirements to adjacent structures on the subject allotment such as detached garages, carports, or similar roofed structure and decks.

Item (f) relates to Performance Requirement G5P2 which only applies to certain Class 9 buildings housing vulnerable occupants. These buildings are excluded from the scope of the bushfire Verification Method so consideration of collapsing vegetation is not required by the bushfire Verification Methods in NCC 2022.

3.5.4 Interpretation of design bushfire

The term 'design bushfire' relates to the characteristics of a bushfire, its ignition, spread and development, which arises from weather conditions, topography, and fuel (vegetation) in a given setting, used to determine fire actions.

The Verification Methods include options for a simple analysis or a complex analysis.

The simple analysis assumes weather conditions with an APE varying from 1:50 years to 1:200 years depending on the Importance Level of the building and then based on the local vegetation and topography determines appropriate design actions associated with the design bushfire(s). It should be noted that the APE relates to the weather conditions when using the simple method.

The APE for a complex analysis requires considering the:

- probability of ignition of a bushfire
- spread to the urban interface adjacent to the subject building
- weather conditions when the fire reaches the interface
- local vegetation and topography.

When undertaking a complex analysis, the APE relates to the actions associated with the design bushfire and vary from 1:500 years to 1:2000 years.

Although the Performance Requirements do not refer to the complex analysis method, since the Verification Method is included in the NCC, it is appropriate to use the method subject to approval from the relevant authority.

3.5.5 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 G5V1 and H7V2.

3.5.6 Determination of APE

The APE for design actions is prescribed in Table G5V1 of Verification Method G5V1 and Table H7V2 of Verification Method H7V2. Table G5V1 is reproduced below as Table 3.2.

Table 3.2 Annual Probability of Exceedance for design actions (NCC Volume One Table G5V1)

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, Section 3.5.5) and selecting the type of analysis (Chapter 4), the appropriate APE is selected.

Example

From Verification Method G5V1 Clause (3)(c), the building is assigned to Importance Level 3.

If the simple analysis method is selected, the APE based on weather conditions would be 1:100 years (refer Table 3.2 or NCC Volume One Table G5V1).

If the complex analysis method is selected, the APE for exposure to bushfire attack for design purposes would be 1:1000 years (refer Table 3.2 or NCC Volume One Table G5V1).

4 Selection and analysis type

4.1 Introduction

The selection of the analysis type, either simple or complex, depends on the specific building solution being considered, available resources and data, and the likely benefits compared to the additional analysis cost if complex rather than simple analysis is used.

In some cases, the supporting data necessary to do the complex 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 a holistic approach to bushfire safety by accounting for fire prevention strategies and management of bushfires before they interact with the built environment. Thus, the complex analysis requires consideration of the following when estimating design actions:

- frequency of ignition
- fire spread to the urban interface
- penetration of the urban interface coincident with severe fire conditions
- the impact of local topography and vegetation.

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 APE 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 weather conditions associated with the prescribed APE). Therefore, the 'prevent ignition' and most of the 'manage fire' branches of the fire safety concepts tree (in Section 4.4) are not applicable. This significantly reduces the level of analysis and need for data.

Reminder

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.

Reminder

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

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

4.2 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. They demonstrate a heavy bias towards Victoria and to a lesser extent New South Wales (NSW). The house loss equivalent includes an adjustment for changes in population and 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.

Since the 2009 fires in Victoria, the proportion of losses occurring in Victoria has reduced. This may not be a long term trend and could be due to short term fluctuations in weather conditions. Bushfire related losses over the last decade derived from various sources, are presented in Appendix C[2].

[2] This data has not been included in the body of this document since reliance had to be placed on media reports to supplement data from technical literature and was unable to be further validated or cross-referenced.

Figure 4.1 Total civilian fatality distribution derived from Blanchi (2012) (Blanchi et al. 2012)

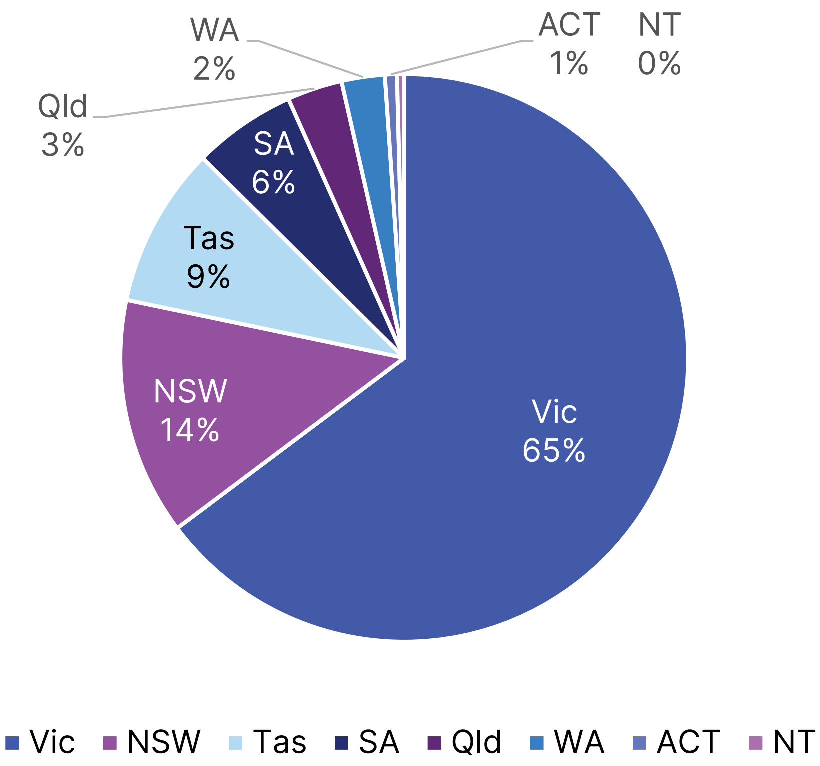
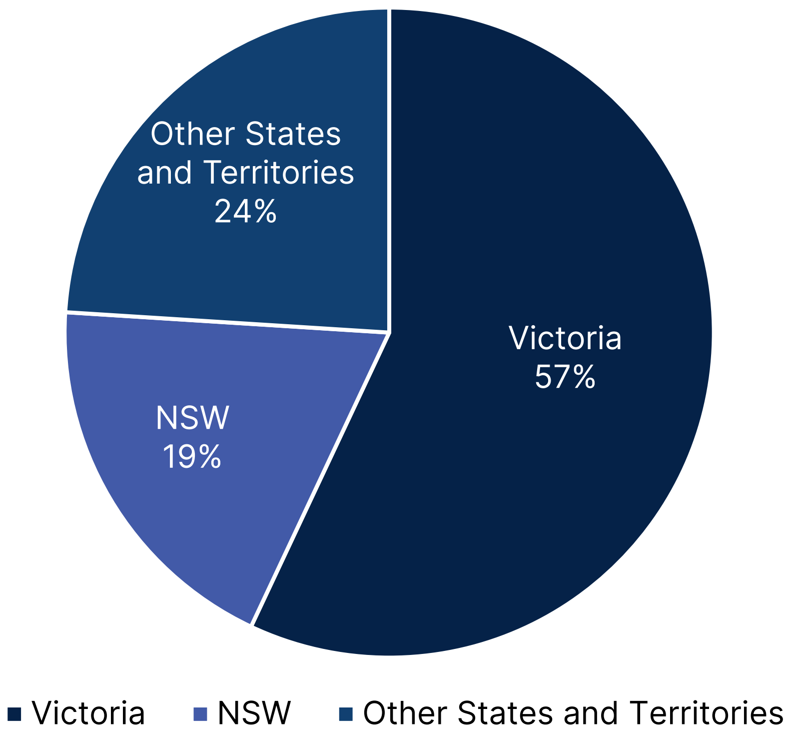


Figure 4.2 Total house loss equivalent derived from Blanchi (2012) (Blanchi et al. 2012)



4.3 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) (Blanchi et al. 2012).

The database does not capture all bushfire loss data but does provide a reasonable sample. Fires such as Black Friday, Black Saturday and Ash Wednesday, whilst grouped as single events, resulted from several 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) (Blanchi et al. 2012)

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 percent 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 7 of these events accounted for approximately 52% of the losses.

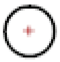
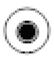
4.4 Bushfire risk management and bushfire resistant construction

The fire safety concepts tree, defined in NFPA[3] 550: Guide to the Fire Safety Concepts Tree (NFPA 2022), 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 G5V1 and H7V2. It shows the interaction with other regulatory and voluntary measures that also impact on the safety of people and buildings and helps determine appropriate bushfire safety designs, the type of analysis for a particular application and data requirements.

The concepts tree uses 2 types of logic gates as shown in Table 4.2.

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 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. These could include the following:

- limited capacity to control or suppress large and severe bushfires
- managing other risks such as landslip
- human involvement
- conflicts with other legislation
- social values such as conservation.

[3] National Fire Protection Association

The comments below the branches in Figure 4.3 highlight some of the more effective mitigation measures and shows where bushfire resistant buildings and structures fit into the tree (indicated by purple text). In subsequent figures, mitigation measures relating to buildings are indicated by purple text.

A large proportion of bushfires start because 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 (e.g. 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 5 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 done. 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

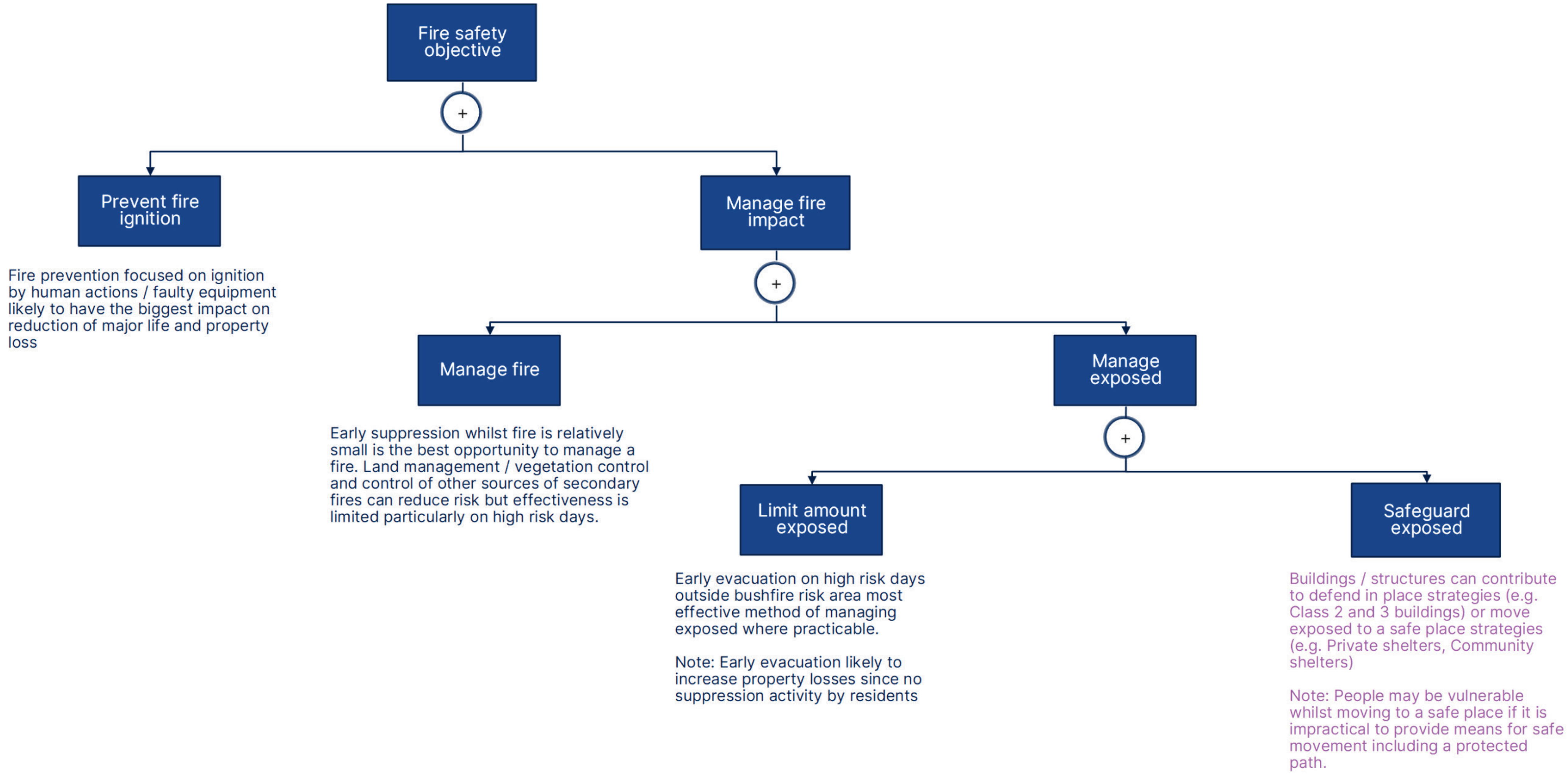


Figure 4.4 Ignition branch of the fire safety concepts tree applied to initial cause of a fire

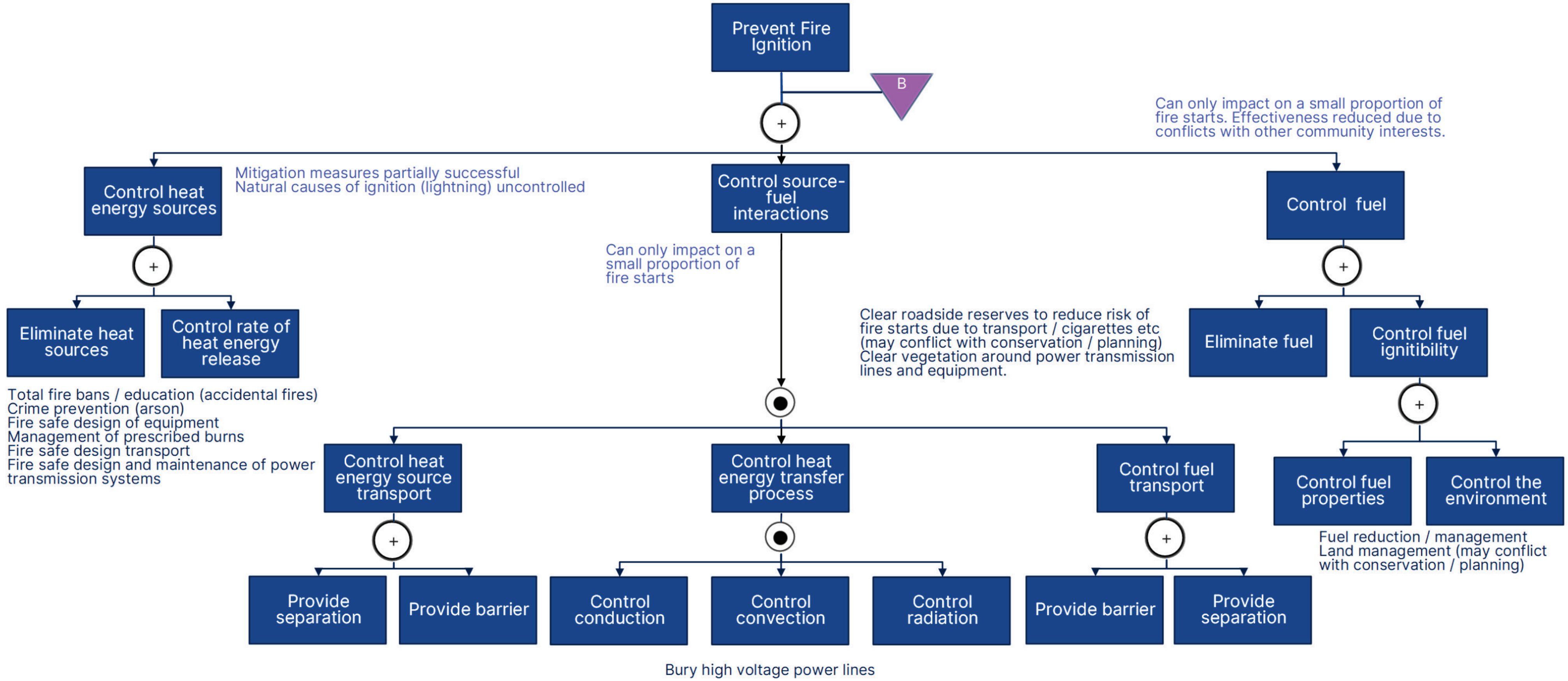


Figure 4.5 Manage fire branch of fire safety concepts tree

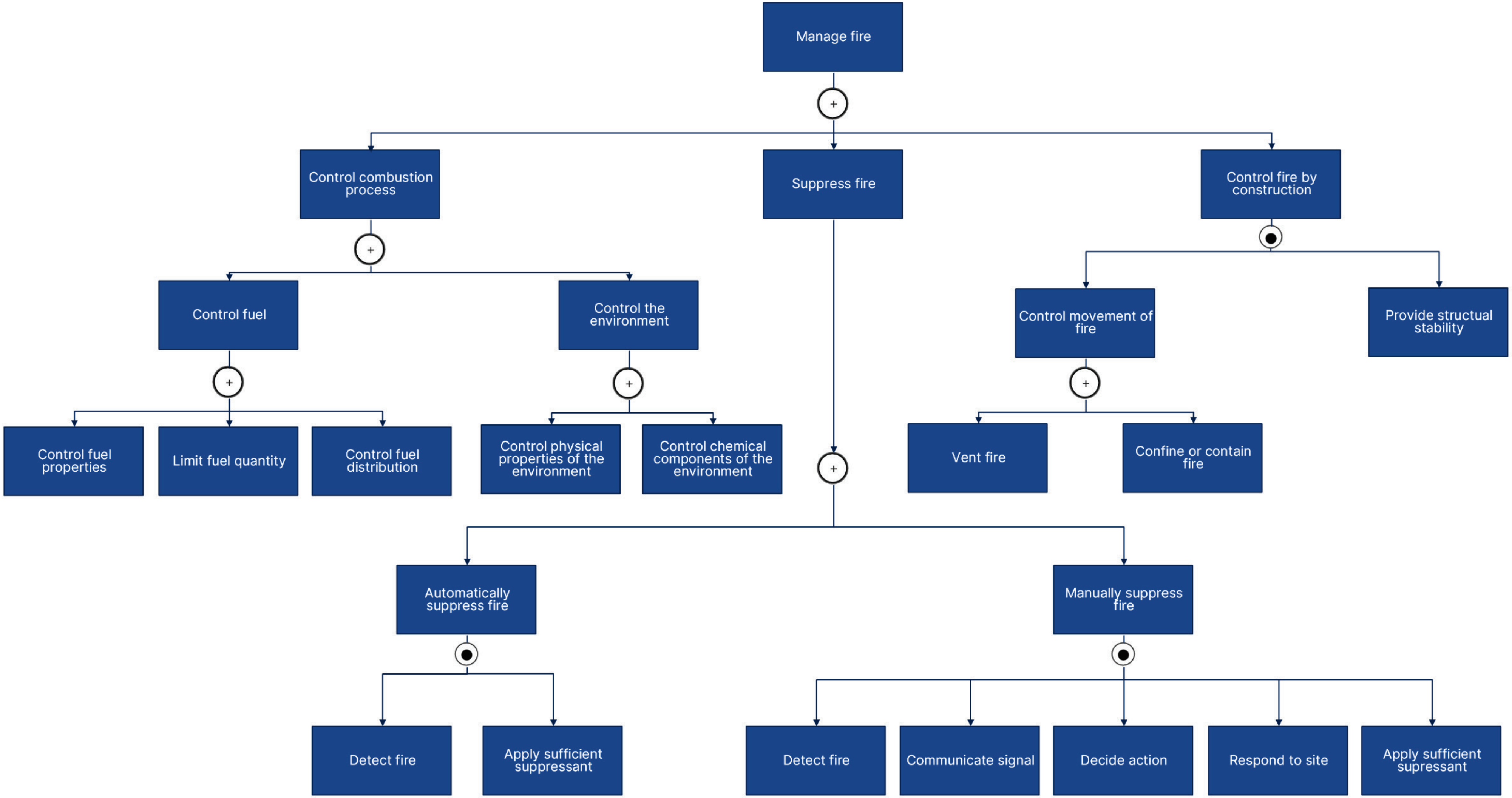


Figure 4.6 Control movement of fire at urban interface sub-branch of control fire by construction

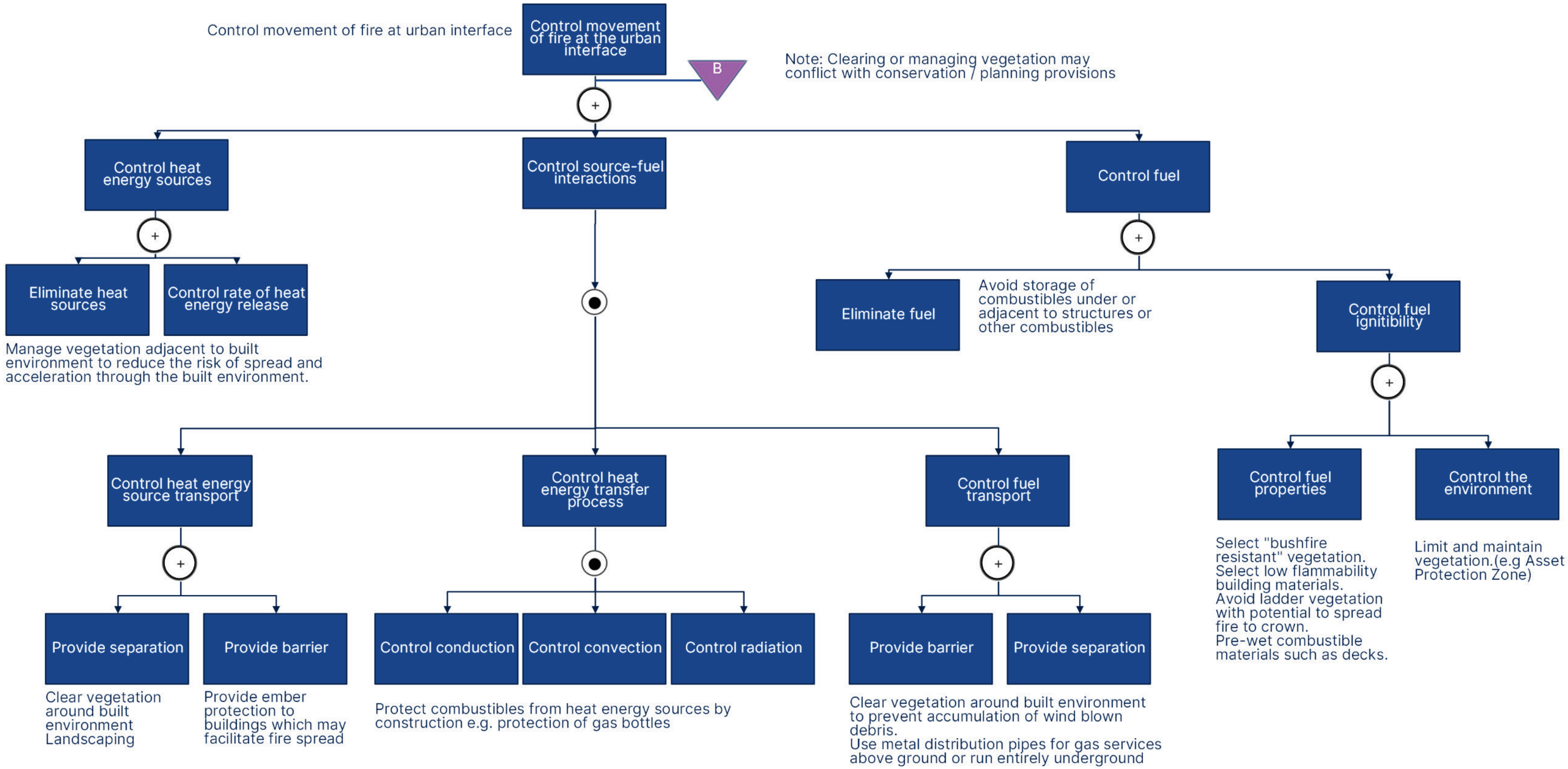


Figure 4.7 Manage exposed branch

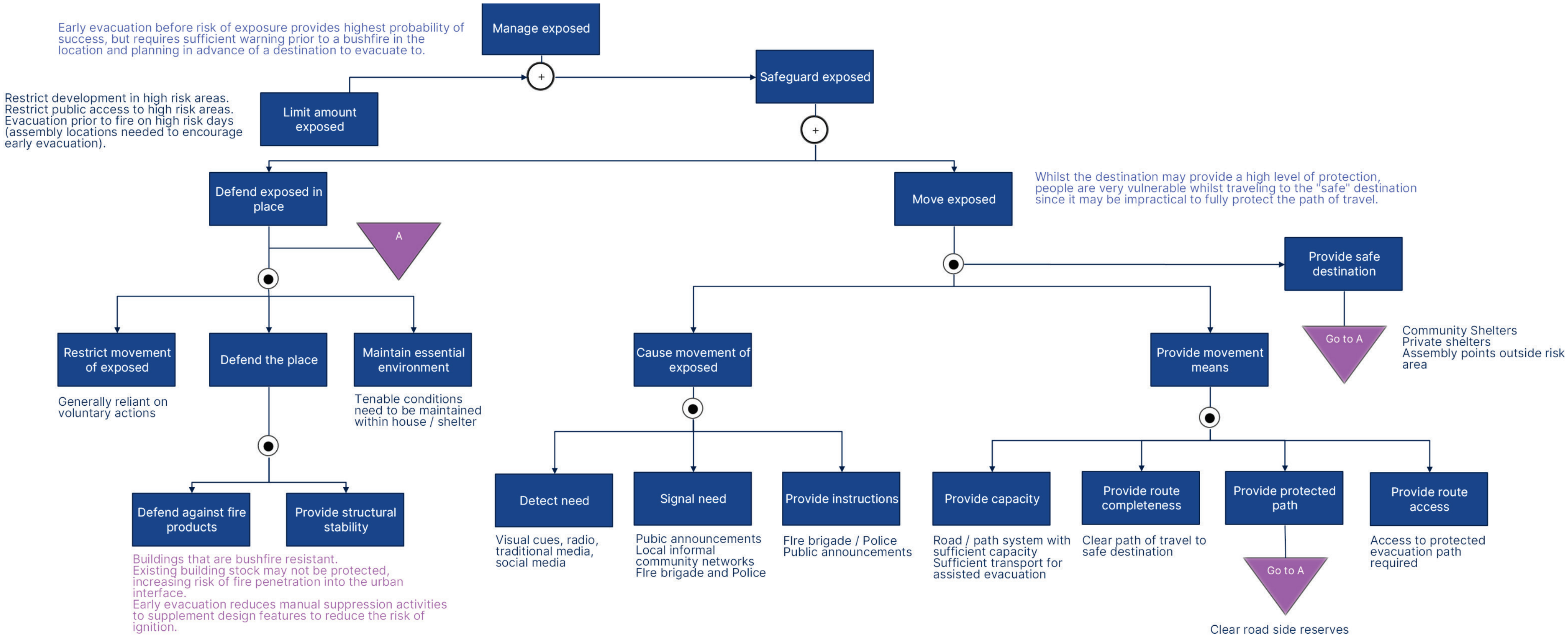
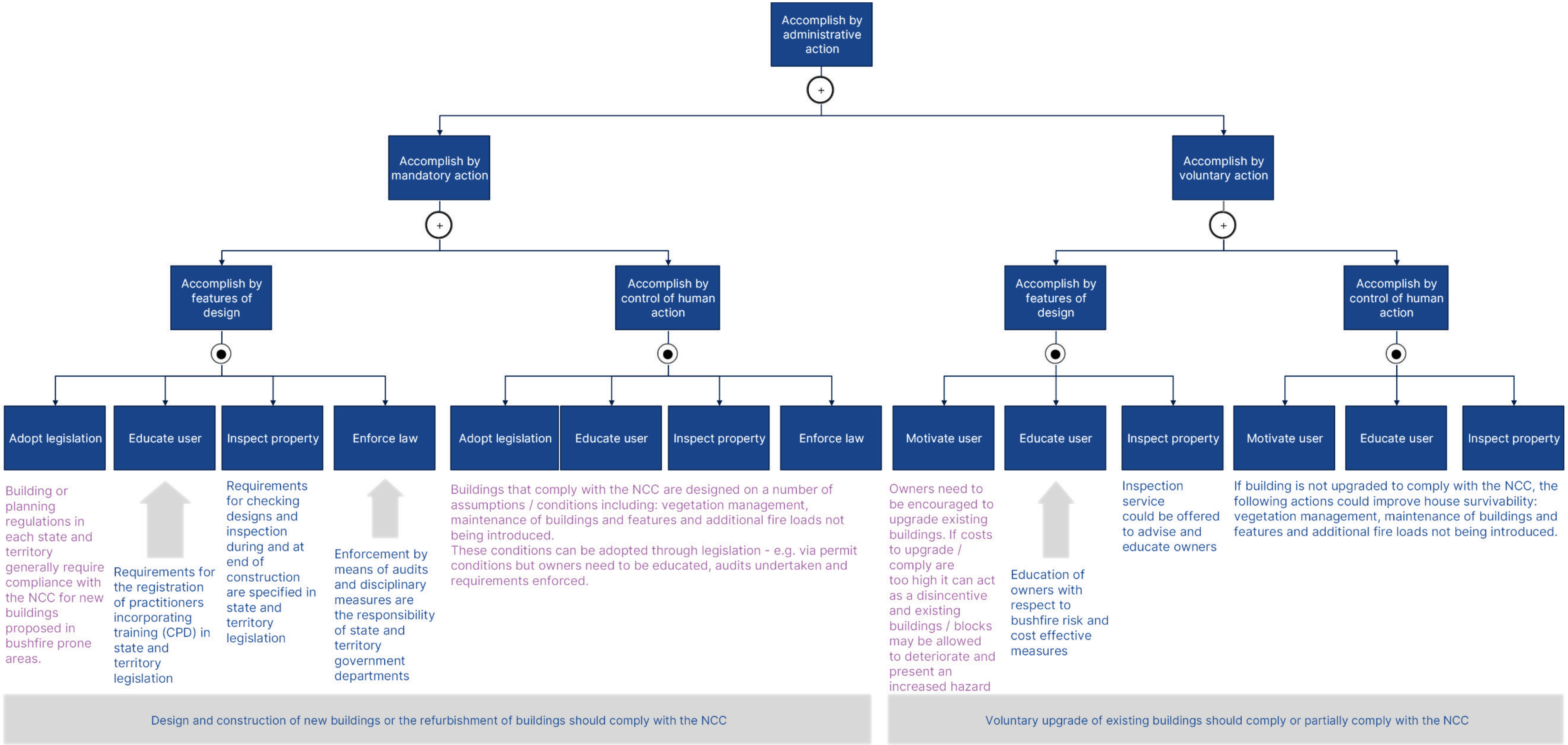


Figure 4.8 Accomplish by administrative action branch applied to design and construction of buildings in bushfire prone areas



5 Determination of design actions

5.1 Overview of bushfire design actions

Verification Methods G5V1 and H7V2, specifically require consideration of the following bushfire design actions for both simple and complex approaches.

This is consistent with the NCC DTS requirements provided in AS 3959-2018, and the following referenced test standards for evaluation of the performance of construction elements.

- AS 1530.8.1-2018 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 1530.8.2-2018 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.

5.2 Parameters for consideration

When establishing bushfire design actions, G5V1 and H7V2 require consideration of reasonable variations in:

- fire weather
- vegetation including fuel load, burning behaviour of the vegetation (including potential for crown fires)
- the distance of the building from vegetation
- topography, including slopes and features that may shield a building
- ignition of adjacent buildings, building elements, plants, mulch, and other materials
- effective size of fire front
- duration of exposure
- flame height
- flame tilt
- flame adhesion to sloping land
- 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 G5V1 and H7V2. For the simple method, the APE for fire weather conditions is directly specified whereas for the complex method, fire weather is 1 of a broader range of parameters considered when defining the APE bushfire exposure.

Interpretations and quantification of design actions

Refer Sections 3.5 and 5.7 for further discussions relating to interpretation and quantification of bushfire design actions.

5.3 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 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. However, the concentrations of embers at a specific distant can still vary considerably with local concentrations occurring due to specific weather conditions and fire behaviour.

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. These should consider the parameters listed above with supplementary exposures applied to address secondary fires as appropriate (refer Section 5.4 for further information on secondary fires).

Example: Bushfire model (e.g. AS 3959-2018)

A typical example of the use of a bushfire model to determine bushfire design actions is the method documented in AS 3959-2018 in conjunction with the test methods described in the AS 1530.8 series, 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. (England et al. 2006).

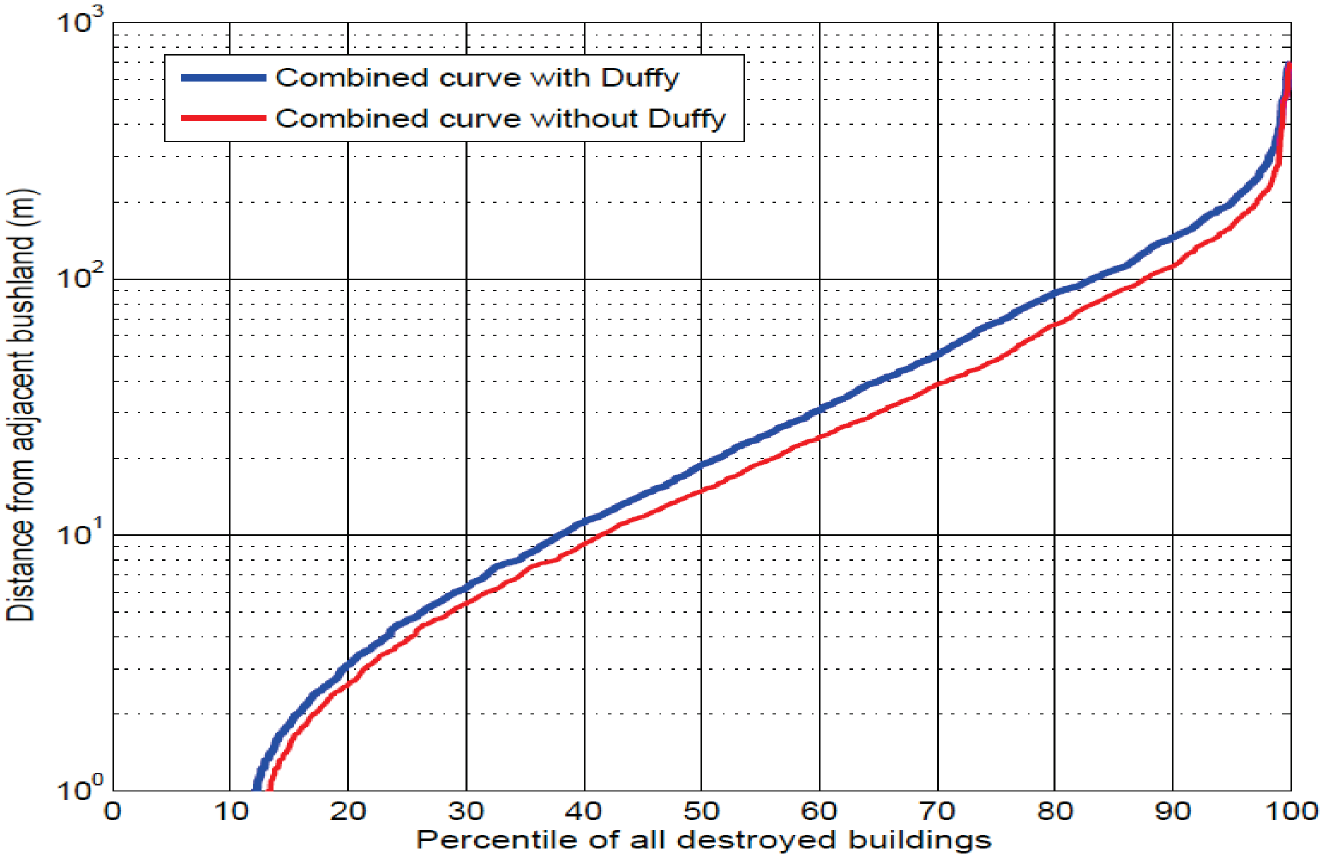
Chen and McAneney (2010) (Chen and McAneney 2010) analysed building losses based on the distance from adjacent bushland after major fires. Their findings are shown in Figure 5.1, which plots the percentile of all destroyed buildings against distance from adjacent bushland with and without the Duffy fires. 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. The results were skewed significantly because minimal house loss occurred within 40 m of the forest simply because there were few houses located within this 40 m zone, but significant house loss still occurred at large distances from the fire. Based on these distributions, it can be observed that typically 40% of house losses occur within 10 m of the “bushland”, 60% within 30 m, over 70% within 50 m, 85% within 100 m and approximately 95% within 150 m.

Therefore, it is considered reasonable to require consideration of vegetation up to 150 m from a building. The complex method does consider vegetation in the broader geographic region to determine the probability of spread to the urban interface.

Figure 5.1 Cumulative distribution of all buildings destroyed in various major bushfires in Australia in relation to distance from nearby bushland from (Chen and McAneney 2010)



Consideration of the impact of vegetation on bushfire design actions

If a form of vegetation does not encroach within 150 m of the building being considered, its contribution to the design actions need not be considered. An exception is some buildings of Importance Level 4 where protection from ember attack and associated secondary fires may be considered beyond 150 m of the vegetation if it is impractical to evacuate the occupants.

5.4 Secondary fires

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

Typical secondary fires scenarios include the following:

- 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.

Note: Combustible mulches can be considered within the category of inappropriate vegetation adjacent to buildings.

The following is an example of a method 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 1530.8.1-2018 if specific data is not available.

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

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, unless an alternative exposure condition can be justified.

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

Fire spread between buildings is required to be addressed under Performance Requirements C1P2 and H3P1 of NCC Volumes One and Two respectively. Therefore, fire spread isn't included in Verification Methods G5V1 and H7V2.

Fire spread between buildings can be evaluated using a Performance Solution to meet Performance Requirements C1P2(1)(c) or H3P1 depending on the building classification.

To meet C1P2(1)(c), Verification Methods C1V1 and C1V2 can be used for undertaking the analysis (or other methods if their use can be adequately justified).

Fire spread between buildings during bushfire events should be evaluated typically under the assumption of no fire brigade intervention unless specific arrangements are in place to ensure fire brigade intervention (refer Section 5.4.1 for further information).

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

The hazards caused by stored materials, mulch, and inappropriate vegetation, are commonly addressed by administrative means by placing controls on the location of these hazards close to a building. This approach is consistent with assumptions underpinning AS 3959-2018 (Standards Australia 2018c).

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.

5.4.1 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 unless specific arrangements are in place for a critical building (e.g. some Importance Level 4 buildings).

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 6.1). However, in response to the findings of the subsequent 2009 Victorian Bushfires Royal Commission Final Report (Teague et al. 2010), a greater emphasis is now placed on early evacuation. Whilst this is expected to reduce fatalities by reducing the numbers of people at risk, a negative consequence is an increase in property losses for buildings constructed to similar standards. Therefore, it should be assumed that in general there will be no fire brigade or occupant intervention with respect to protecting a property, unless specific measures and training are provided.

Fire brigade or occupant intervention

When determining design fire actions and/or the responses of elements of construction no modification should be made for fire brigade or occupant suppression activities except where specific measures are in place to facilitate safe intervention.

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 prior to evacuation.

5.4.2 Impact of wind

Severe bushfires are commonly accompanied by high winds which can, under severe bushfire conditions, be induced directly by the fire. High winds can potentially “open buildings up” prior to the passage of the fire front by dislodging roof tiles and breaking windows, increasing susceptibility to ember/flying brand attack (Ramsay et al. 1987).

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 and burning embers.

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. There are practical limitations and methods to address some of these limitations as discussed in Chapter 6.

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.

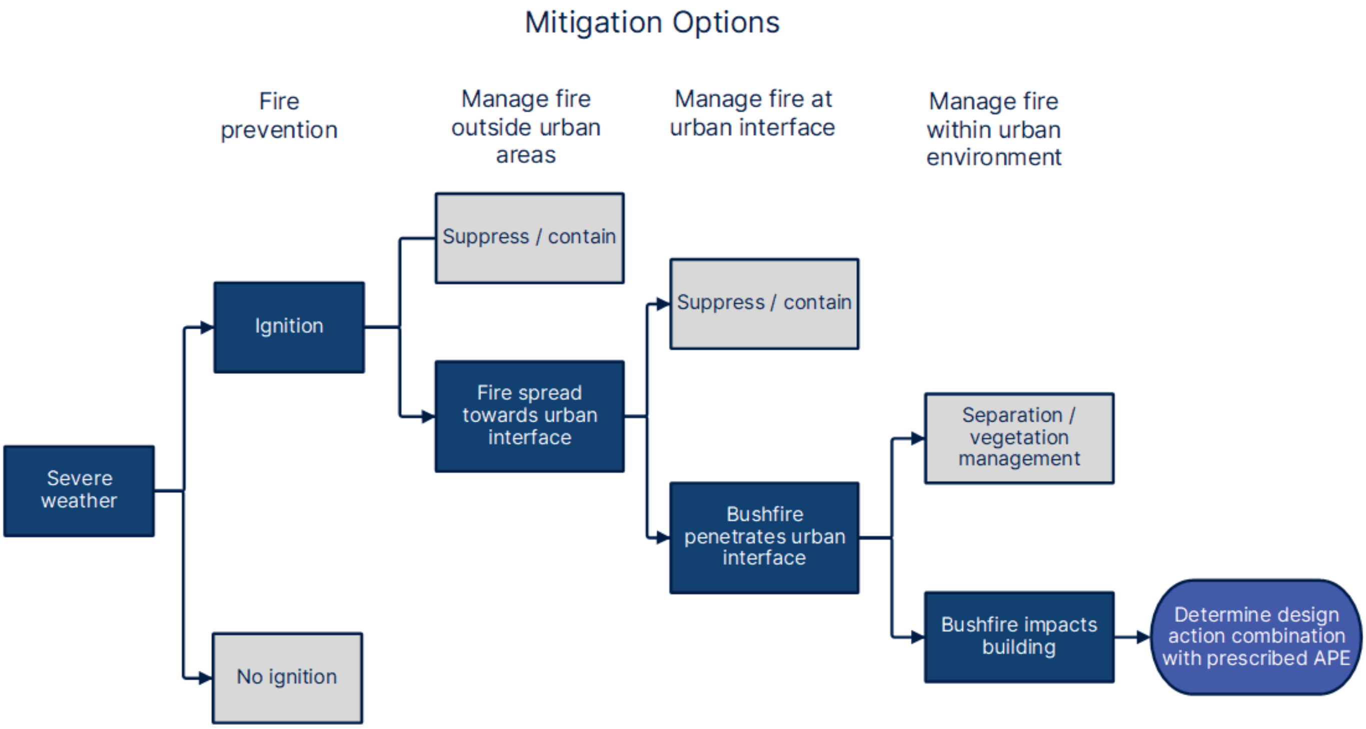
5.5 Complex analysis

Exposure of a structure to a bushfire event does not occur because of extreme weather conditions alone, but rather because of a series of events as indicated in the simple event tree shown in Figure 5.2. This figure has been derived from the fire safety concepts tree analysis and is consistent with the following requirement from the Verification Method.

Table notes for Table G5V1 Annual APE for design bushfire actions

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 5.2 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 building solutions tailored to the specific risks at a particular location.

It also encourages and considers 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 to improve the consistency of approaches throughout a township or suburb. This will help 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 AS 3959 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 5.2 is consistent with several quantitative bushfire risk assessment models under development (e.g. see Atkinson et al. (2010) and Cechet et al. (2014)).

Earlier work by Bradstock and Gill was referenced by Atkinson et al. (2010), which proposed the relationship:

$$D = I \times S \times E \times G \times H$$

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

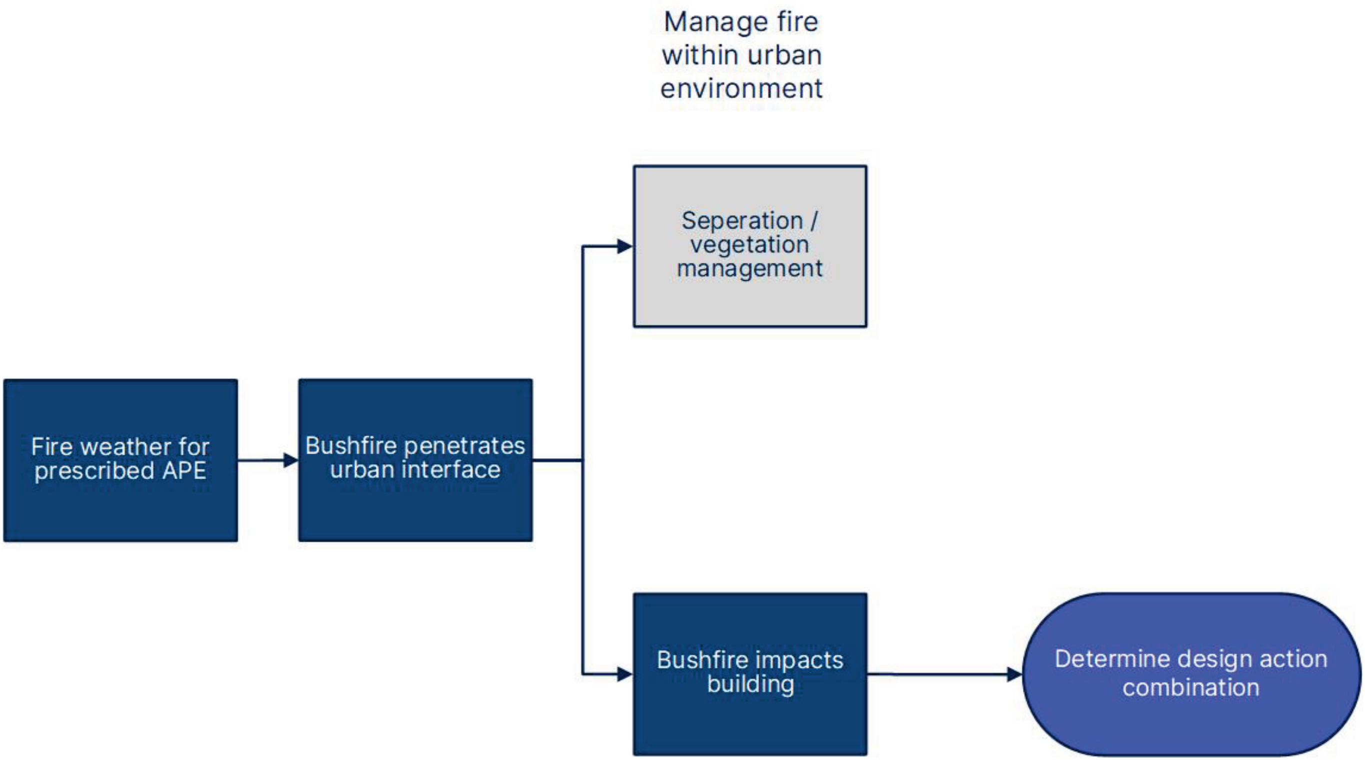
H is the probability of fire propagating within buildings.

This relationship identifies similar events to Figure 5.2 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 G5V1 and H7V2.

5.6 Simple analysis

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 5.3. This approach is consistent with the approach specified in AS 3959-2018, referenced in the DTS Provisions. However, in some circumstances this may tend to be overly conservative, particularly where the frequency of bushfires is low.

Figure 5.3 Determination of exposure to design actions - simple method



5.7 Specification of bushfire design actions

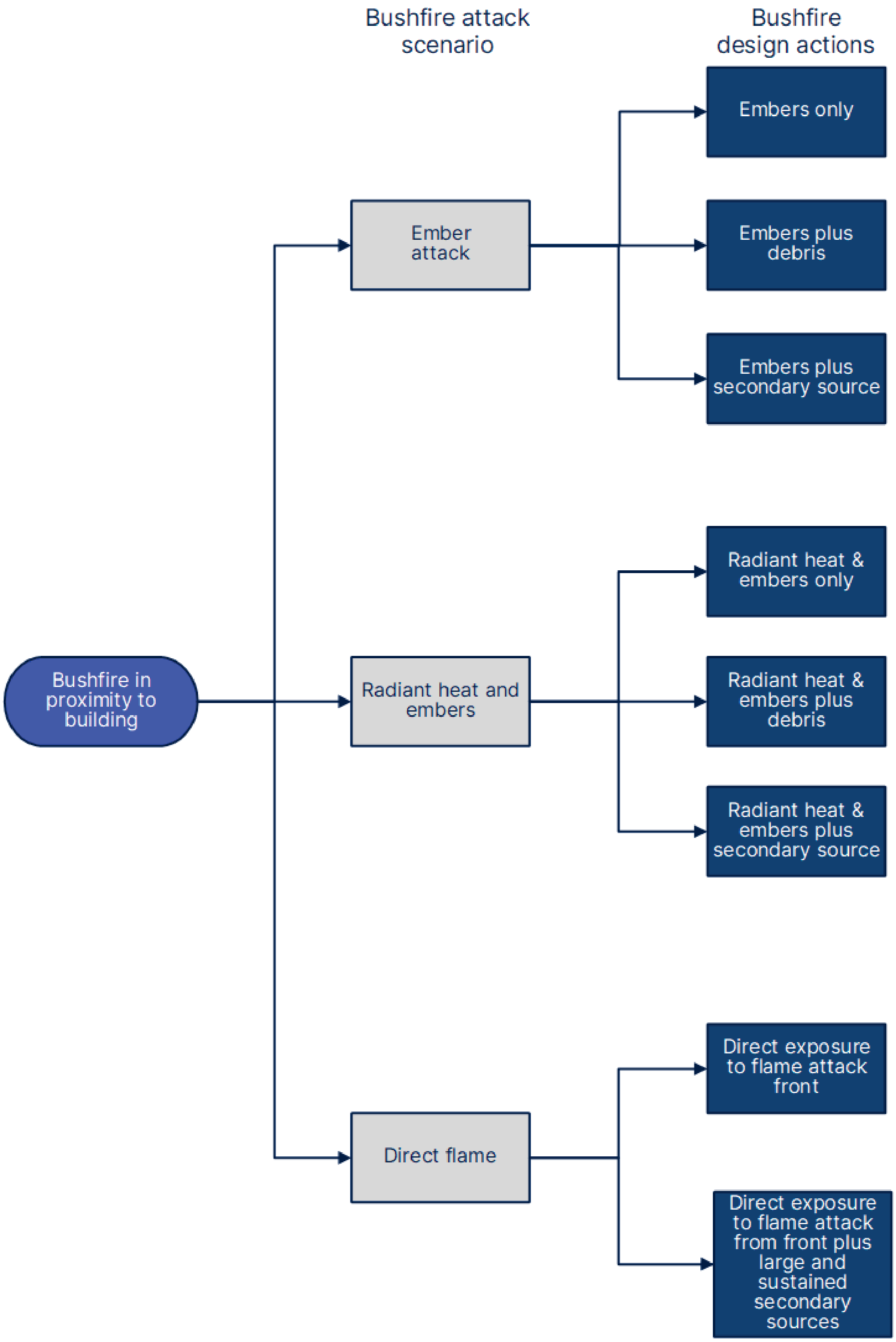
5.7.1 Introduction

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 rationalisation to some extent to facilitate comparison and evaluation of the performance of elements of construction.

A typical rationalisation is shown in Figure 5.4.

Figure 5.4 Bushfire design actions



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 to determine compliance with the Verification Method. This avoids the need to adjust the bushfire actions to account for 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 (Gould et al. 2008), which was an investigation into the behaviour and spread of high-intensity bushfires in dry eucalypt forests. This investigation was aimed to quantify age-related changes in fuel attributes and fire behaviour in dry eucalypt forests typical of southern Australia.

5.7.2 Ember (fire brand) attack

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

Project Vesta 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 (ember) density/m^2 at a given distance, d

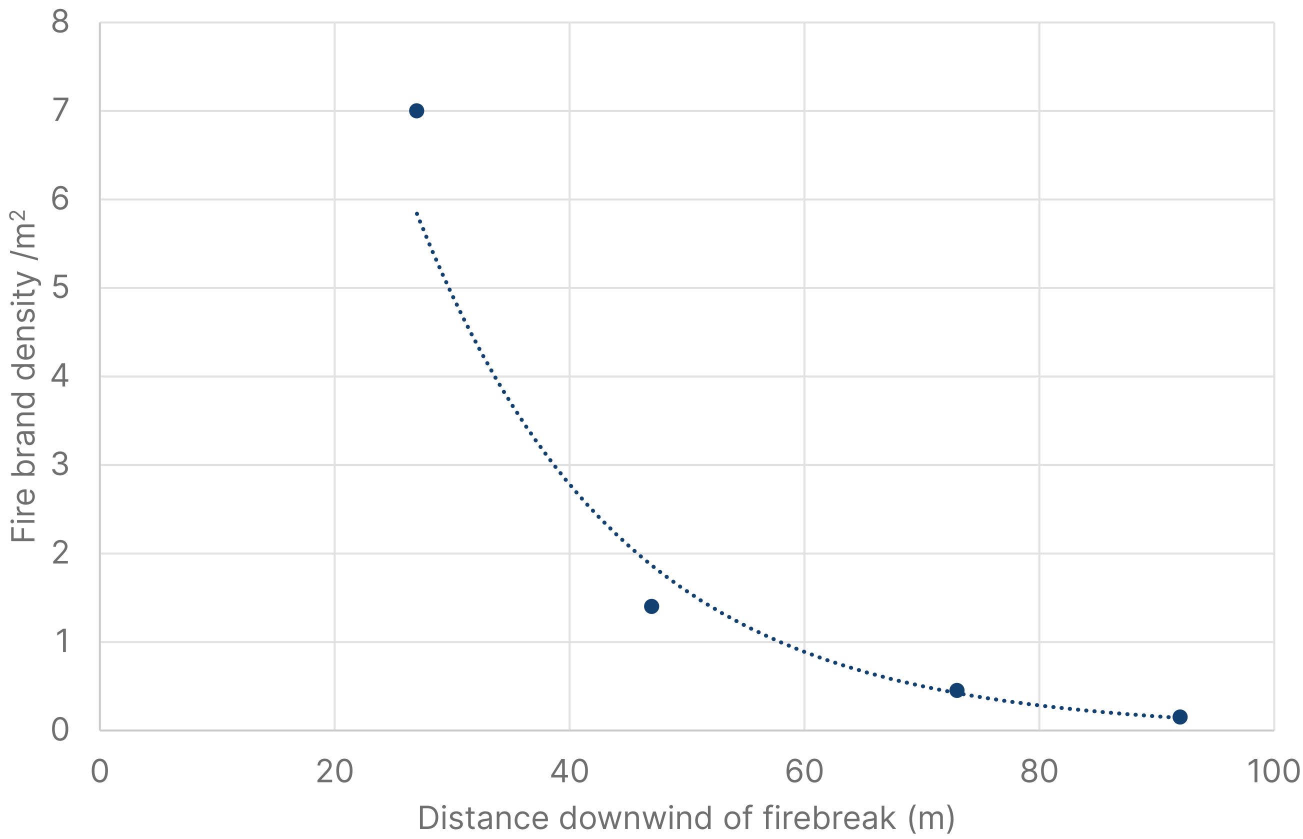
D_o is the fire brand density/m^2 immediately downwind of the fire break

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' is shown in Figure 5.5.**Error! Bookmark not defined.**

Figure 5.5 Maximum fire brand density downwind of Fire D (Jarrah forest with 5-year-old fuel) adapted from Gould et al. (2008)



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

The Project Vesta report 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. This can be used to estimate the probability of ignition of secondary fires or embers penetrating openings.

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

Single flaming embers that do not settle on or against a combustible surface can be treated as a small flaming ignition source, which has the greatest relevance for elements additionally exposed to radiant heat.

Significant research is currently being undertaken relating to the ignition of combustible elements due to collections of flaming embers, debris or mulch ignited by embers. Temperatures generated by collections of burning embers/debris can also be sufficient to initiate localised structural failures of non-combustible elements in addition to ignition of combustible materials.

Examples of current research include:

- modelling of wood surface ignition by wildland fire brands (Matvienko et al. 2022)
- thermal characterisation of fire brand piles (Hakes et al. 2019)
- effect of fire brand size and geometry on heating from a smouldering pile under wind (Tao et al. 2021).

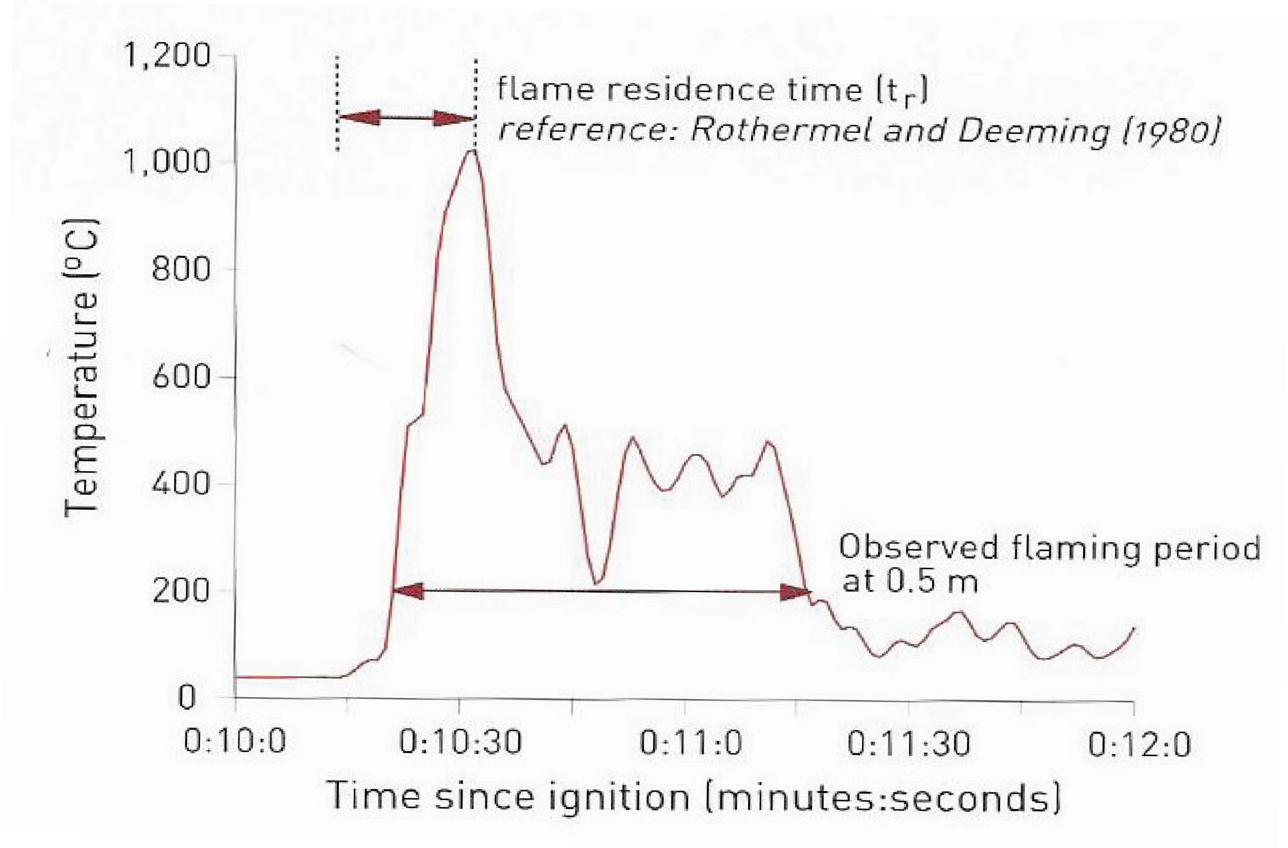
It is impractical to carry out large scale tests with differing air flows for routine verification of proprietary construction systems. Methods such as AS 1530.8.1-2018 have tended to adopt larger crib sizes and include a range of crib sizes that can be selected to generate heat fluxes like piles of embers and debris burning under wind assisted conditions.

5.7.3 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 (Rothermel and Deeming 1980). A typical time temperature history from Project Vesta (Gould et al. 2008) is shown in Figure 5.6 with a flame residency period of approximately 20 seconds and an observed flaming period approaching 1 minute.

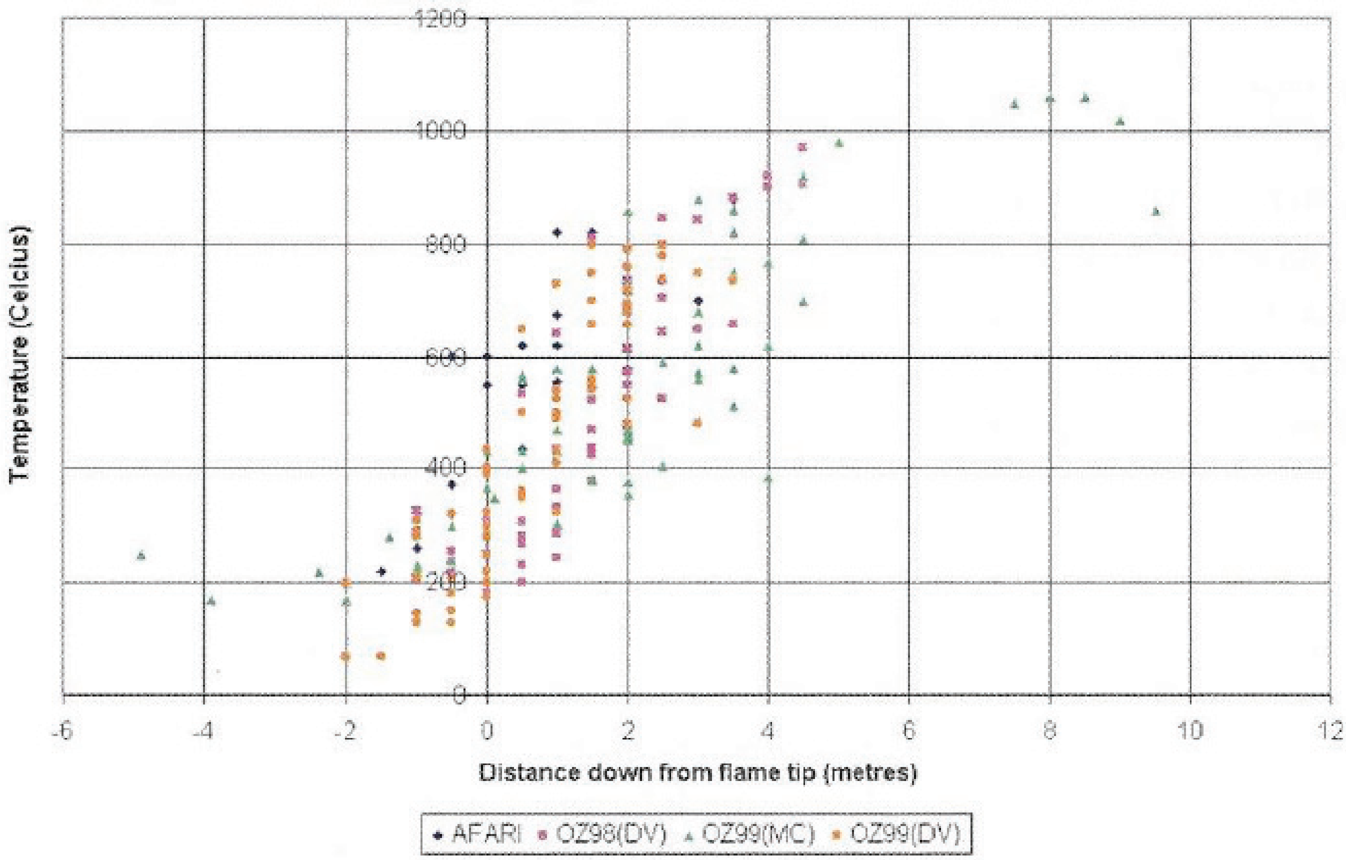
Figure 5.6 Flame residency time and the observed flaming period at 0.5 m, 75 m from ignition line (fire Mc 08/A) (Gould et al. 2008)



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 5.7, extracted from (Gould et al. 2008).

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 5.7 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 (Gould et al. 2008)

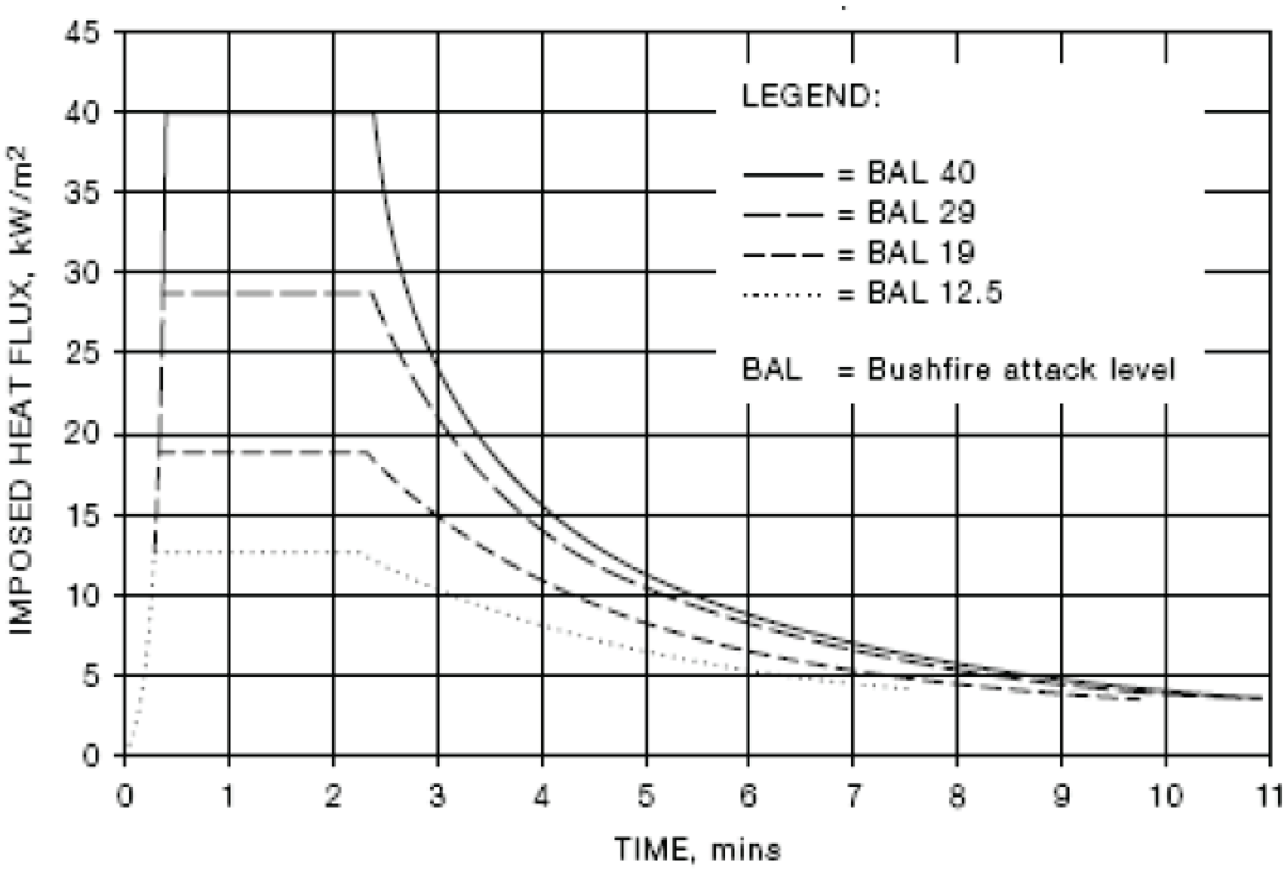


AS 3959-2018, referenced by the NCC DTS Provisions, adopts a simplified method to calculate exposure to radiant heat from the fire front. The flame height is calculated and a uniform emitted heat flux over the total flame height and a default fire front width of 100 m is assumed. A flame residency period (maximum emitted heat flux) of approximately 2 minutes is defined by AS 1530.8.1-2018, together with the heating profiles shown in Figure 5.8.

The AS 3959 approach also adopts a flame inclination that maximises heat transfer between the fire front and building, rather than considering the effect of wind. This tends to 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 3959-2018/AS 1530.8.1-2018 BALs for evaluation of the performance of elements of construction.

Figure 5.8 Imposed heat flux from AS 1530.8.1-2018 for various BALs

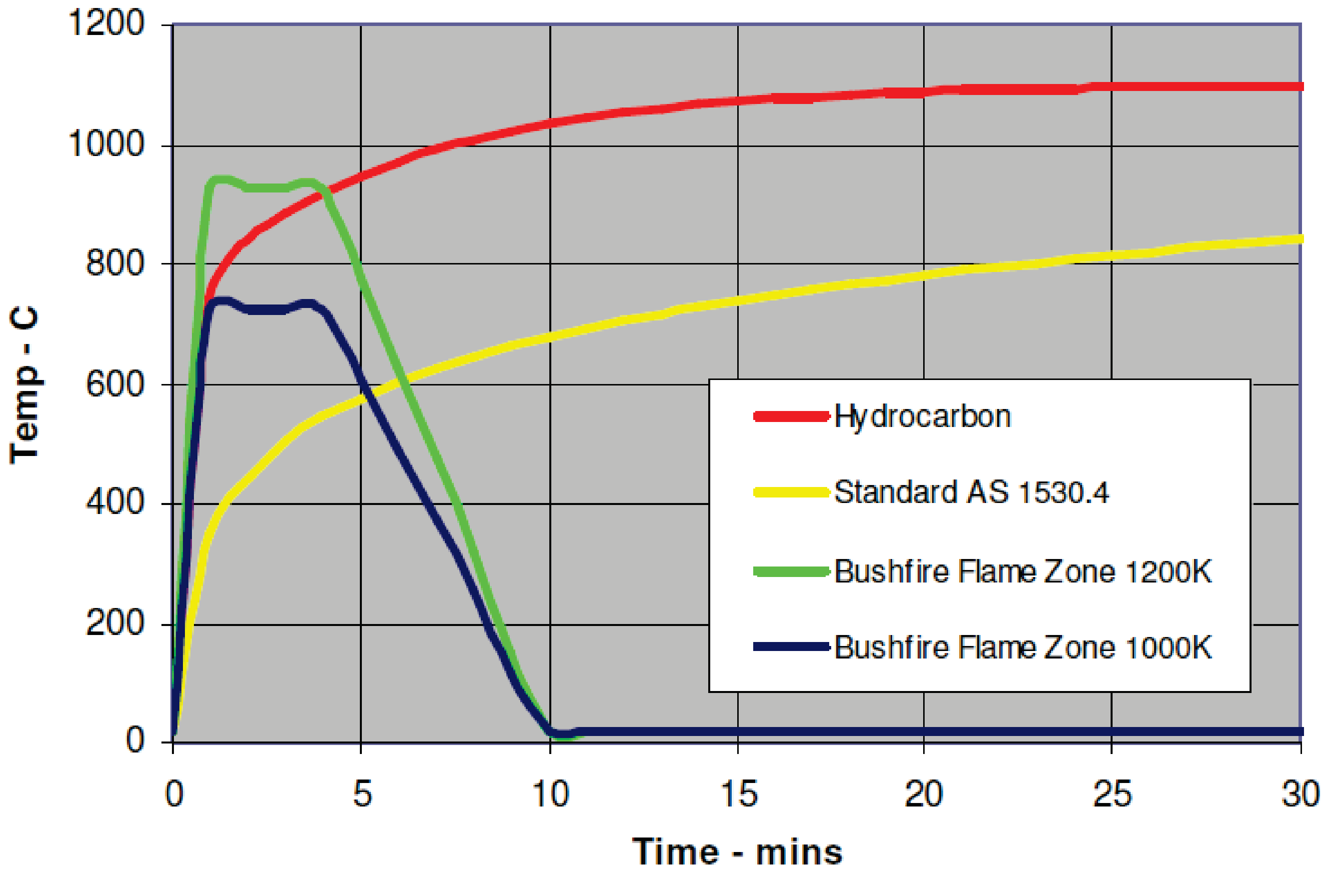


5.7.4 Direct flame exposure

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 5.8 can be generated with a rapid rise, sustained peak and decay period using assumed flame temperatures as shown in Figure 5.9.

Figure 5.9 Direct flame exposure conditions based on assumed flame temperatures and heating profile of AS 1530.8.1-2018



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

The approach used in AS 1530.8.2-2018 uses the AS 1530.4-2014 standard heating regime with 30 minutes of 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. This is 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 1 test to another and temperatures will tend to be lower close to the flame tip as identified above.

From Figure 5.9, 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 following:

- flame temperature close to the point of contact
- severity of exposure.

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.

5.7.5 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 1530.8.1-2018.

During the development of AS 1530.8.1-2018, 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 5.10.

Figure 5.10 Determination of mass burning rate for debris when exposed to radiant heat (England et al. 2008)

The mass loss rates were compared against similar tests undertaken with 3 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 localised 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.

5.7.6 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. These can be used to define design fires.

For fire spread between buildings, the criteria specified in C1V1 and C1V2 of NCC Volume One can be used to define the required exposure.

6 Determination of response to bushfire attack

6.1 Overview

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. This will enable the probability of fire ignition within the building when exposed to design actions to be determined.

This should then be compared with the acceptance criteria in the Verification Methods, which require the probability of fire ignition within a building not to exceed 10%.

Verification Methods G5V1 and H7V2 require the assessment process to include consideration of the following:

- the probability of non-complying construction of critical aspects of an approved design
- the probability of critical aspects of an approved design being fully functional during the life of the building
- inclusion of safety factors
- sensitivity analysis of critical aspects of a proposed design.

The NCC specifies the minimum technical requirements of new buildings and new building work. The responsibility for the administration of construction and maintenance of buildings is addressed directly by each state and territories' legislation. A maximum 10% probability of fire ignition within the building as stated in the bushfire Verification Methods should be based on compliant construction of critical aspects of the approved design. This includes ongoing maintenance of the critical aspects of the design, so the intended design performance is maintained.

However, this does not absolve designers, suppliers, owners, occupiers and regulatory authorities of responsibility for addressing safety throughout the building life cycle. The inclusion of above dot points within the requirements of G5V1 and H7V2 serves to highlight the need for consideration by practitioners during the design/construction phases and the need to provide information to owners, occupiers and regulatory authorities of critical aspects of the design that require regular inspection and maintenance.

Chapter 7 provides supplementary information relating to administration of building works, compliance and maintenance.

Alert: Interpretation of acceptance criteria

The NCC Verification Method specifies maximum 10% probability of fire ignition 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.

However, G5V1 and H7V2 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 should document how these matters have been addressed and estimated probabilities for compliant construction and maintenance of critical features. This should be considered by the relevant regulatory authority when reviewing the design. It is recommended that practitioners check with the appropriate state or territory authority regarding expectations in relation to compliance and maintenance of buildings in bushfire prone areas.

Further guidance relating to the administration of building works, compliance and maintenance is provided in Chapter 7.

The response of elements of construction to bushfire attack can be evaluated using several 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 assessing evidence of suitability.

The performance at the interfaces between elements of construction should 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 landscape features. Testing under steady state conditions (constant airflow or minimal air flow) may yield unrealistic results and the performance of many construction elements may vary across a range of wind velocities. For example, the 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. However, 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 maybe 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.

6.2 Standard test methods

The following performance criteria are specified in the test methods of AS 1530.8.1-2018 and AS 1530.8.2-2018. Both standards are referenced by AS 3959-2018 and therefore are part of the DTS Provisions for construction in bushfire prone areas. However, the methods are also relevant for Performance Solutions.

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

(1) 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

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

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

(4) radiant heat flux 365 mm from the non-fire side of the specimen in excess of 15 kW/m2 from glazed and un-insulated areas during the test

(5) 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

(6) radiant heat flux 250 mm from the fire exposed face of the specimen greater than 3 kW/m2 between 20 minutes and 60 minutes after the commencement of the Part 1 test or 60 minutes after commencement of the Part 2 test

(7) 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 AS 1530.8.1-2018 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 flaming ember attack. Burning cribs are also applied on surfaces where there is potential for debris and/or ember accumulation. The entry of burning embers with sufficient energy to cause ignition is addressed by applying limits to the size of through gaps that are permitted to form during the test.

The design actions have been previously discussed in Section 5.7 and additional discussion on the application of performance criteria for building ignition is in Section 3.5.2.

The results are expressed in terms of BALs.

For example, a specimen tested in accordance with AS 1530.8.1-2018 that satisfied the following performance criteria at a peak heat flux of 40 kW/m^2 with a Class AA crib, could be classified as BAL: AA40.

AS 1530.8.2-2018 applies to elements potentially exposed to full flame engulfment from the fire front and utilises the standard heating regime of AS 1530.4-2014 in lieu of the burning cribs and radiant heat. It can also be used for determining the response of elements to large secondary fires such as adjacent buildings.

For a specimen tested in accordance with AS 1530.8.2-2018 that satisfied the appropriate performance criteria, the element of construction could be classified as BAL: FZ (i.e. Bushfire Attack Level: Flame Zone).

Reference should be made to the AS 1530.8 series of standards and England (England et al. 2008) for further information.

Whilst the test methods do not specifically address wind, the following observations indicate how the test methods have compensated for these limitations as far as practicable:

- penetration of the façade by embers is addressed by limiting gap sizes
- conservative assumptions have been made deriving the test exposure conditions including timber crib sizes (refer Sections 5.7 and 3.5.2)
- self-extinguishment of flaming combustion on the exposed façade is required after exposure to the heating regimes.

6.3 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 6.1, which was extracted from the results of surveys in the Otway Ranges after the Ash Wednesday fires presented by Ramsay et al. (Ramsay et al. 1987, Ramsay et al. 1996).

Table 6.1 Relative risks of destruction of houses based on results from (Ramsay et al. 1987 and Ramsay et al. 1996)

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, greater than 12°	0.8
Roof Slope	Flat, less than 12°	1.0
Elevation	Slab on Ground	0.2
Elevation	High, greater than 2 m	0.4

Items	Options	Relative risk of destruction
Elevation	Low, less than 2 m	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
Surrounding Veg	Trees	1.0

6.4 Calculation/modelling

In some instances, the performance of construction elements 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. This provides further confidence in calculations.

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

6.5 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. Full scale field tests can be very costly and may not be able to be undertaken in severe bushfire weather conditions. However, they do provide directly applicable results for the specific conditions of exposure, although cost may prohibit investigation of the repeatability of results.

Intermediate scale experiments with simulated bushfire exposures lie between these extremes and the AS 1530.8 test methods were developed by refining and standardising earlier fire experiments done to evaluate materials under simulated bushfire conditions.

Another example of an intermediate scale test involves burning ember generators. This can expose elements of construction to simulated ember showers. A description of typical apparatus is provided by Manzello (2014), but work is ongoing in relation to defining representative ember densities and properties.

6.6 Estimating probability of fire ignition

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 1 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 ignition when exposed to design actions for a brick veneer house

The design is a brick veneer house built on a concrete slab with structural timber framing and steel roof cladding. A simple roof profile with a gradient greater than 25° without roofing valleys was selected to reduce the risk of debris/leaf litter collecting on the roof, together with metal leaf guards 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 house perimeter and a vegetation management plan specified.

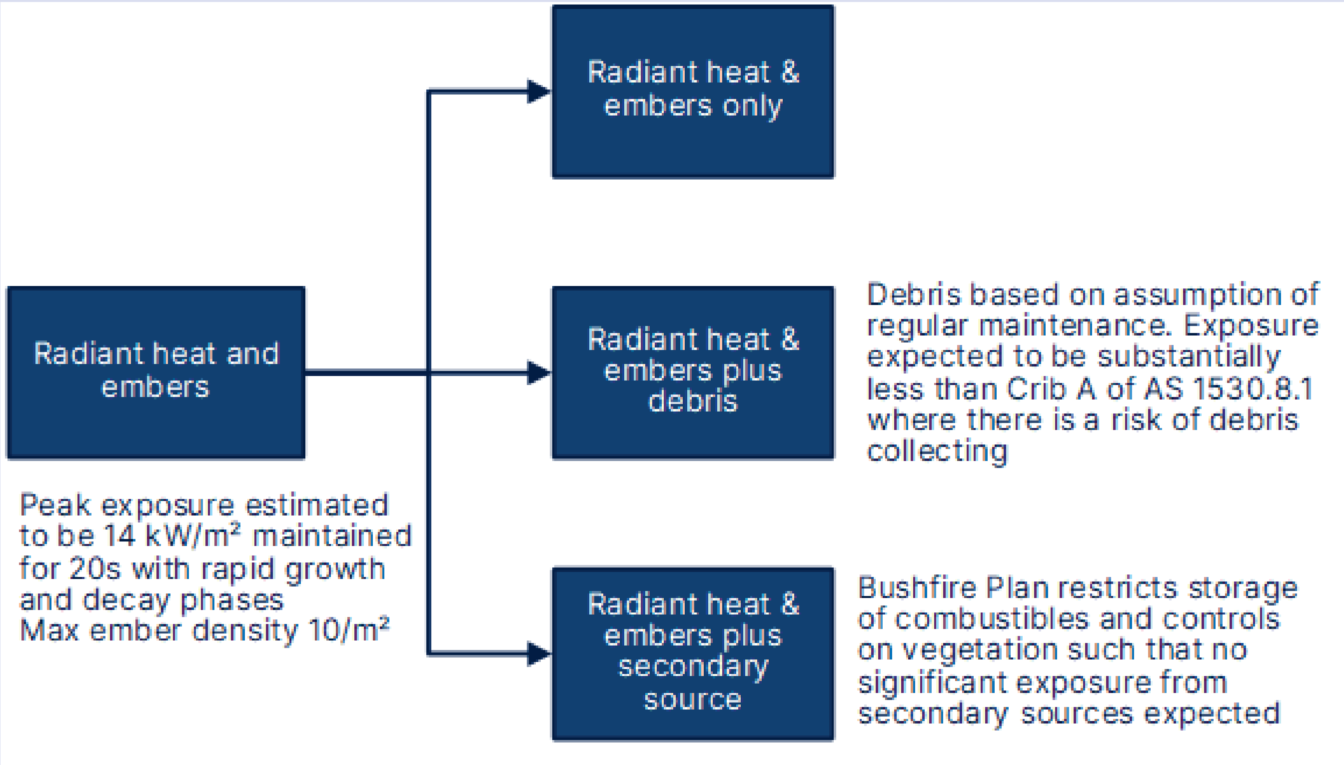
The Verification Method is interpreted as requiring the probability of compliant construction and maintenance of the bushfire safety plan to be estimated separately (see Chapter 7). Therefore, the estimate of the probability of fire ignition is based on assumed compliant construction at the time of the fire.

The design actions are summarised in Figure 6.1 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 done. The details were generally typical of BAL 29 construction defined in AS 3959-2018.

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

Figure 6.1 Derived exposure and design actions



The results of this exercise are summarised in Table 6.2.

Table 6.2 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 internally	Effectiveness of ember resistance to be considered if penetrations are exposed.
Heating Ventilation and Air-conditioning Systems (HVAC)	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.

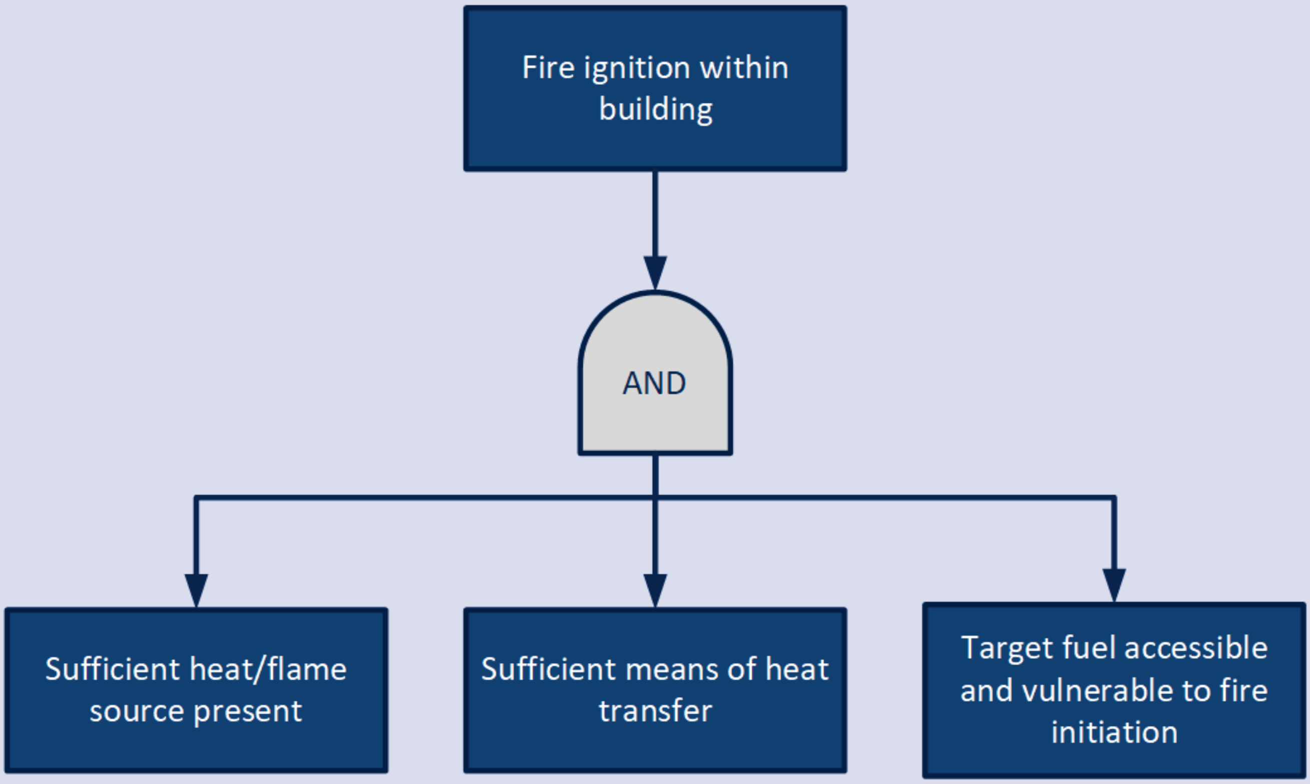
Based on the preliminary analysis, the following critical vulnerabilities were identified as requiring further analysis:

- 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 are shown in Figure 6.2.

Figure 6.2 Upper branches of a general fault tree for fire ignition



This can be applied to fire ignition 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 ignition for each of the critical vulnerabilities when exposed to the appropriate design actions. The probabilities should then be summed to provide a total risk of fire ignition within the building when exposed to the design actions.

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 conduction and the heat/flame source is the radiant heat profile with a potential for an ember penetrating an opening in the sheet. This provides an additional ignition source.

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

Window and door openings

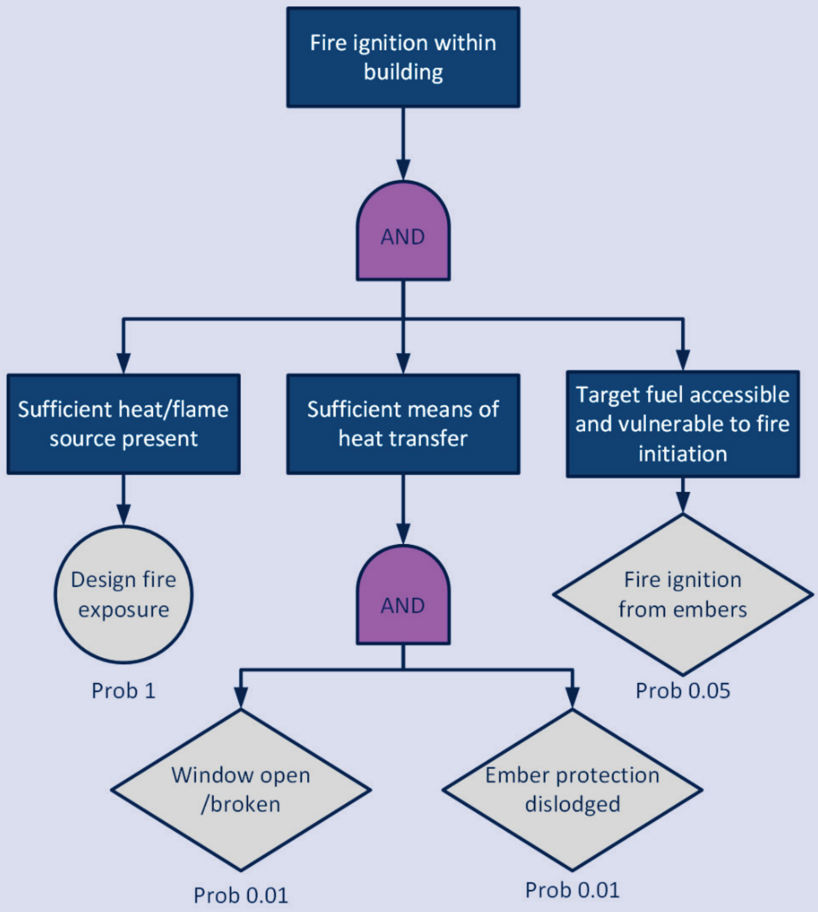
The design of windows and location of sills considered the exposure to collections of burning debris was unlikely. It was determined that the design action would be radiant heat and exposure to embers. Since the exposure to radiant heat is relatively low (14 kW/m^2) and of a short duration (20 seconds) with no exposure to burning debris, it was determined that if the window was closed the probability of internal fire ignition would be very low. This was based on test data and material properties. The probability of fire ignition 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 6.3 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 and therefore probability of fire ignition due to spread through any window assuming uniform exposure would be approximately:

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

Figure 6.3 Fault tree for fire ignition due to ember entry of window opening

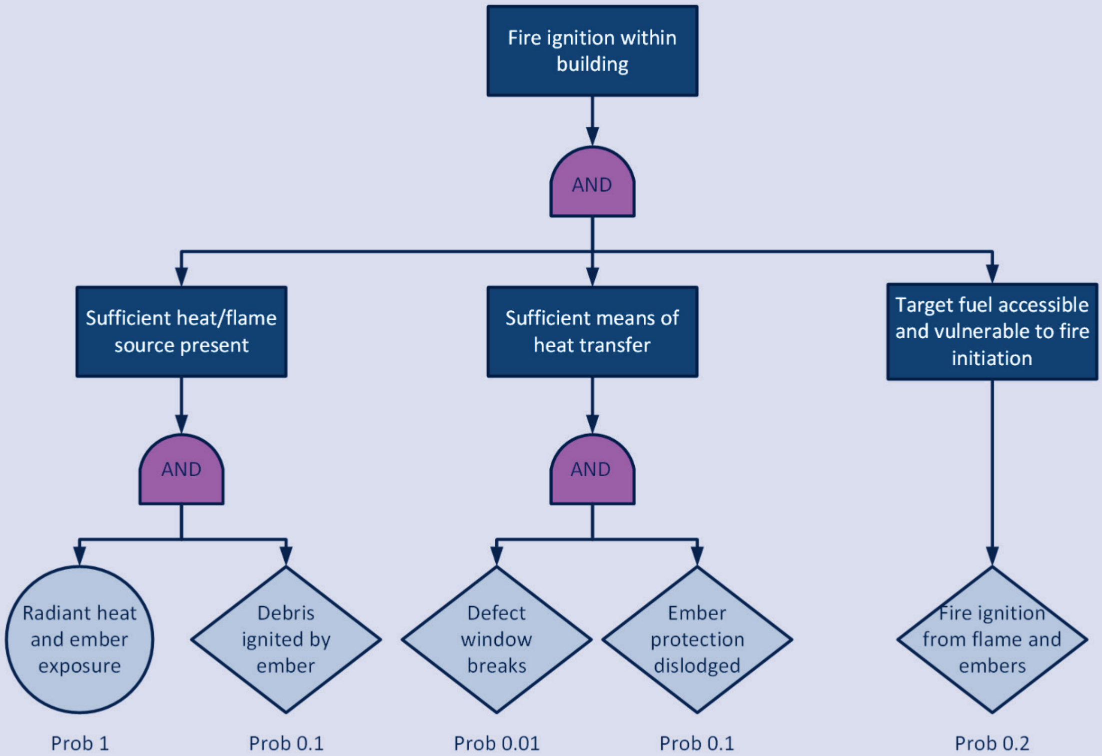


There is an additional risk of exposure to burning debris with respect to the door openings because of the horizontal surface at the threshold allowing collection of debris. It was determined, with the bushfire safety plan in place, debris collection at the base of the 2 external doors would present an exposure to the door less than the equivalent of an AS 1530.8.1-2018 Type A crib. The door assembly design had previously been successfully tested and achieved a BAL 29 rating with the Type A crib. 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 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 6.4 shows the estimated probabilities. This yields a probability of spread through a door due to burning debris and subsequent fire ignition of approximately:

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

Figure 6.4 Fault tree for fire ignition due to burning debris at door base



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

The building has 2 doors, therefore the probability of fire ignition due to spread through any door (assuming uniform exposure) would be approximately 5×10^{-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 7). 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 ignition 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 2 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. The results showed the sealant could be ignited but as the radiant heat was reduced, the sealant self-extinguished and remained in place. 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 ignition through compliant sealant details would be very small and no further analysis was required.

Consolidation of probability of fire ignition

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

The very low probability of fire ignition 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 ignition can be expected to still provide acceptable performance.

7 Administration of building works, compliance and maintenance

7.1 Introduction

The general design process for G5V1 and H7V2 was shown in Figure 3.1.

The NCC specifies the minimum technical requirements of new buildings and new building work. The responsibility for the administration of construction and maintenance of buildings being addressed directly by each state and territories legislation. However, it is critical the designers of buildings adequately communicate:

- what is required as evidence of suitability
- required methods of installation
- requirements for maintenance and inspection.

This will help ensure that the required bushfire resistance is achieved through the life of the building.

This is emphasised in the bushfire Verification Methods G5V1 and H7V2 which 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. This further highlights the importance of compliance.

The following general guidance in relation to administration of building works, compliance, and maintenance is to assist in addressing the risk from non-compliant construction and inadequate maintenance. However, note that there are differences in the approaches used by states and territories that may require specific 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.

The implementation and maintenance plan should include the following as a minimum.

- Target estimates for the probability of non-complying construction of critical aspects of the approved design and the estimates of the target 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 to achieve the target estimates.

- Administrative measures necessary to achieve the target estimates, 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 information sources 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, territory and 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 that can be incorporated in event trees for quantifying the probabilities. Typical examples are provided in Figure 7.1 and Figure 7.2.

Figure 7.1 Typical event tree for estimating probability of non-complying construction critical to performance

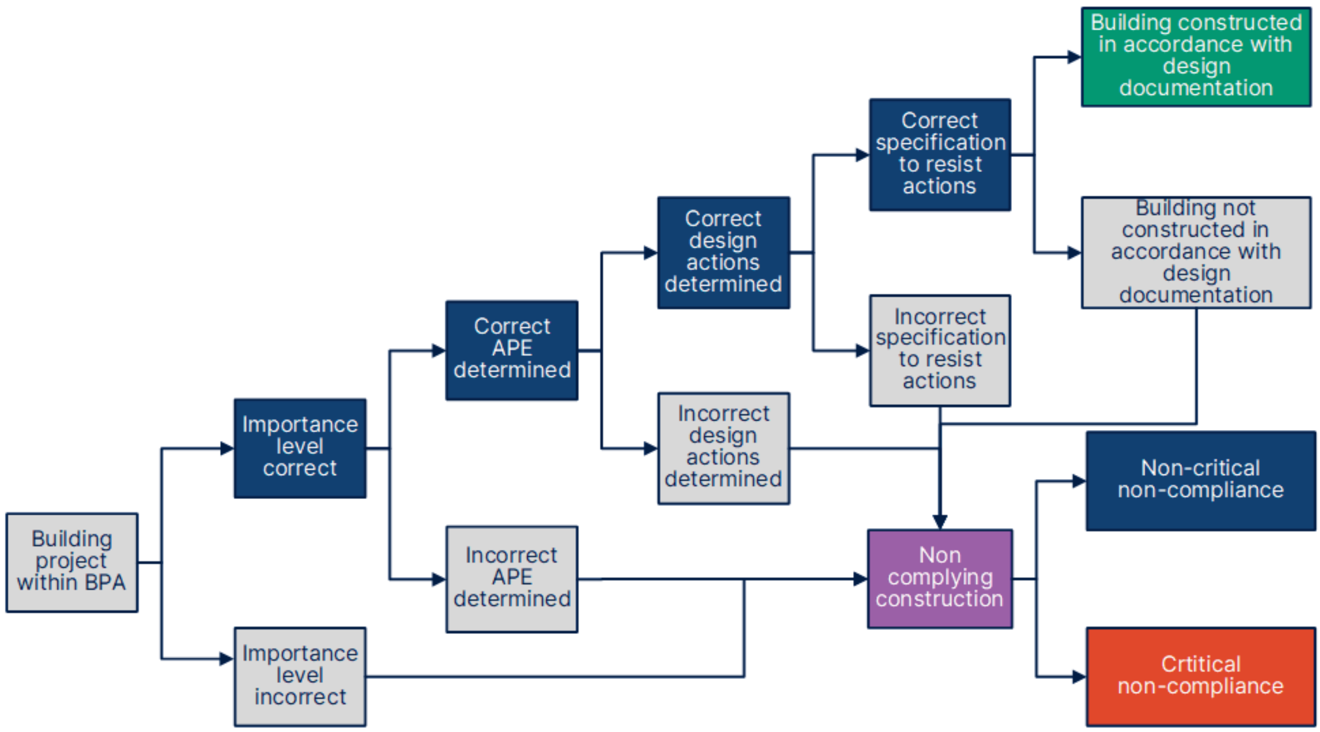
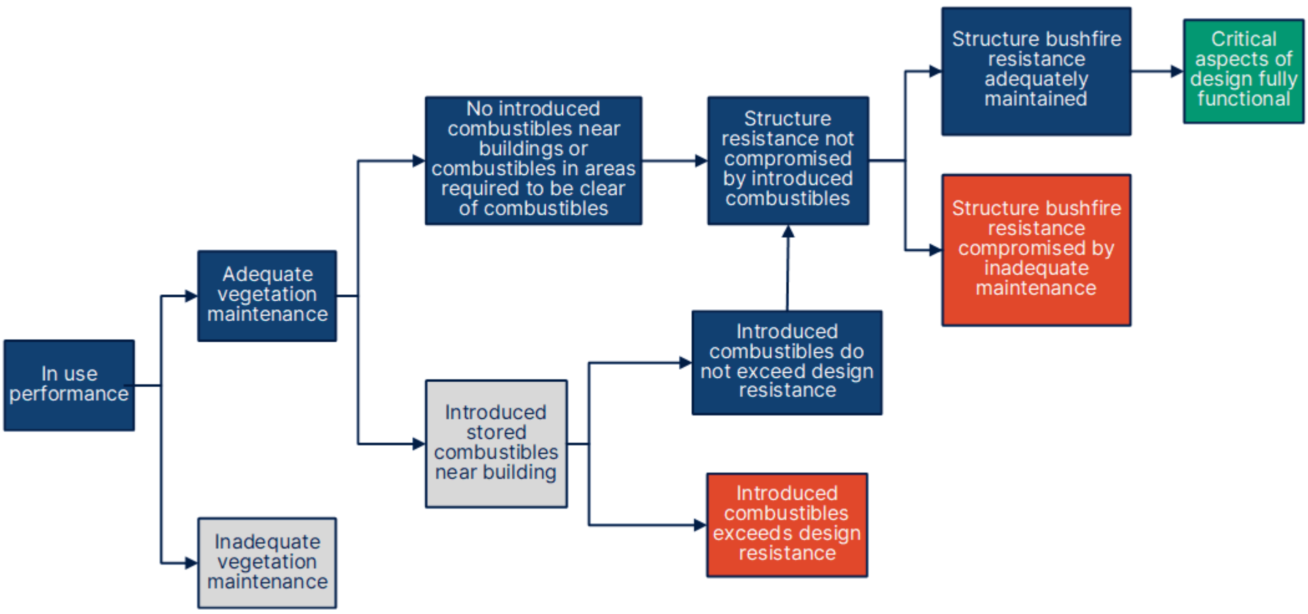


Figure 7.2 Typical event tree for estimating probability of critical aspects of an approved design being fully functional during the life of the building



Subjective judgements will be required in most instances. 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.

7.2 Bushfire safety plan

The outcome of a design developed in accordance with G5V1 or H7V2 should be documented in a bushfire safety plan or equivalent document. This 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.

A bushfire safety plan 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 G5V1 or H7V2
- 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/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.

Complete versions should be provided to the appropriate authority(s) and the building owner.

A summary of the critical information from the bushfire safety plan should also be developed. The summary should contain an explanation of the fire safety strategy, the requirements for the maintenance of vegetation, combustible materials and relevant building fire safety features. A copy of the summary should be in the electrical supply enclosure or similar, so it is readily accessible and secure for building occupants.

Reminder - Expected Standards Australia publication

At the time of preparing this handbook, a Standards Australia project had commenced to develop a new handbook (SA HB 208) for "Maintenance of construction in bushfire-prone areas". It is expected to address many of the above issues in detail.

Appendices

Appendix A Abbreviations

The following table, Table A.1 contains abbreviations used in this document.

Table A.1 Abbreviations

Abbreviation	Meaning
ABCB	Australian Building Codes Board
APE	Annual Probability of Exceedance
AS	Australian Standard
BAL	Bushfire Attack Level
DTS	Deemed-to-Satisfy
FZ	Flame Zone
HVAC	Heating, Ventilation and Air-Conditioning
IGA	Inter-government agreement
ISO	International Standardization Organisation
N/A	Not Applicable
NCC	National Construction Code
NFPA	National Fire Protection Association (US)

Appendix B Compliance with the NCC

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

State and territory governments are responsible for regulation of building, plumbing and development/planning in their respective state or territory.

The NCC is a joint initiative of the Commonwealth and state and territory governments in Australia 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 and territory 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.

B.2 Demonstrating compliance with the NCC

Compliance with the NCC is achieved by complying with the NCC Governing Requirements 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.

There are 3 options available to demonstrate compliance with the Performance Requirements. These are:

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

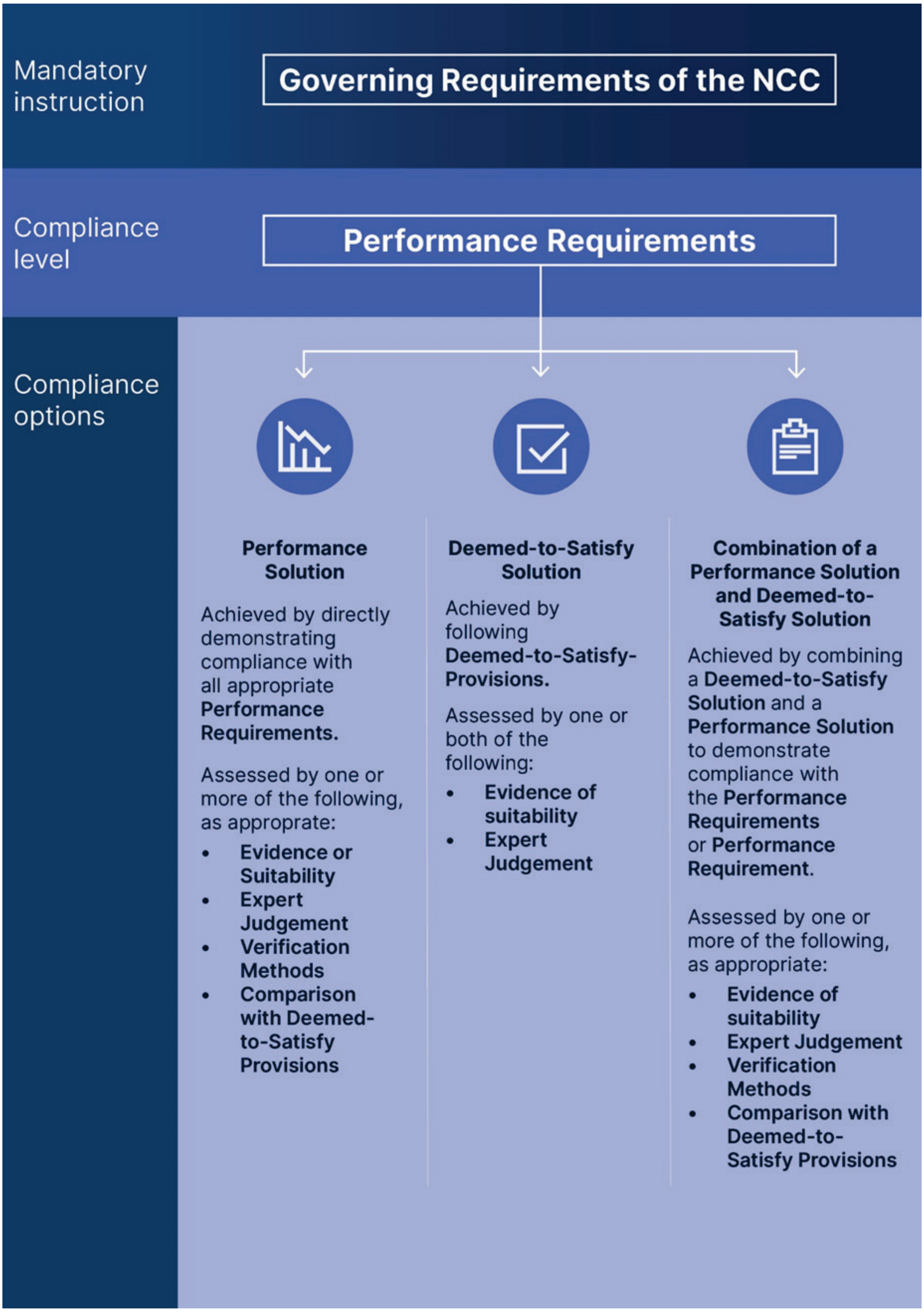
All compliance options must be assessed using 1 or a combination of Assessment Methods, as appropriate. These include:

- 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 B.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.

Figure B.1 Demonstrating compliance with the NCC



Appendix C Supplementary data

Consolidated data from technical literature and/or formally reported statistics relating to the risk to buildings and people for the whole of Australia, or by state and territory over the last 10 years are not readily available.

The following estimates were derived from various sources including press articles and should therefore be considered indicative estimates only.

Sources for data relating to life loss and house losses in addition to general media are:

- Impact of Australia's catastrophic 2019/20 bushfire season on communities and environment (Filkov et al. 2020)
- Bushfire deaths in Australia, 2010 - 2020 (Coates 2020).

Between 2009 and 2020[4]:

- the mean number of houses lost per annum due to bushfires was 410, with over 67% occurring in the 2019-20 season.
- the mean number of fatalities per annum due to bushfires was 5.9, with over 53% occurring in the 2019-20 season.

The total number of houses lost and fatalities due to bushfires are plotted in Figure C.1 and Figure C.2, respectively. The distribution of these losses between the states and territories are shown in Figure C.3 and Figure C.4, respectively.

[4] 11 financial years from 2009-10 to 2019-20. This also applies to the Figures in this Appendix.

Figure C.1 Approximate number of houses lost to bushfires in Australia 2009 to 2020

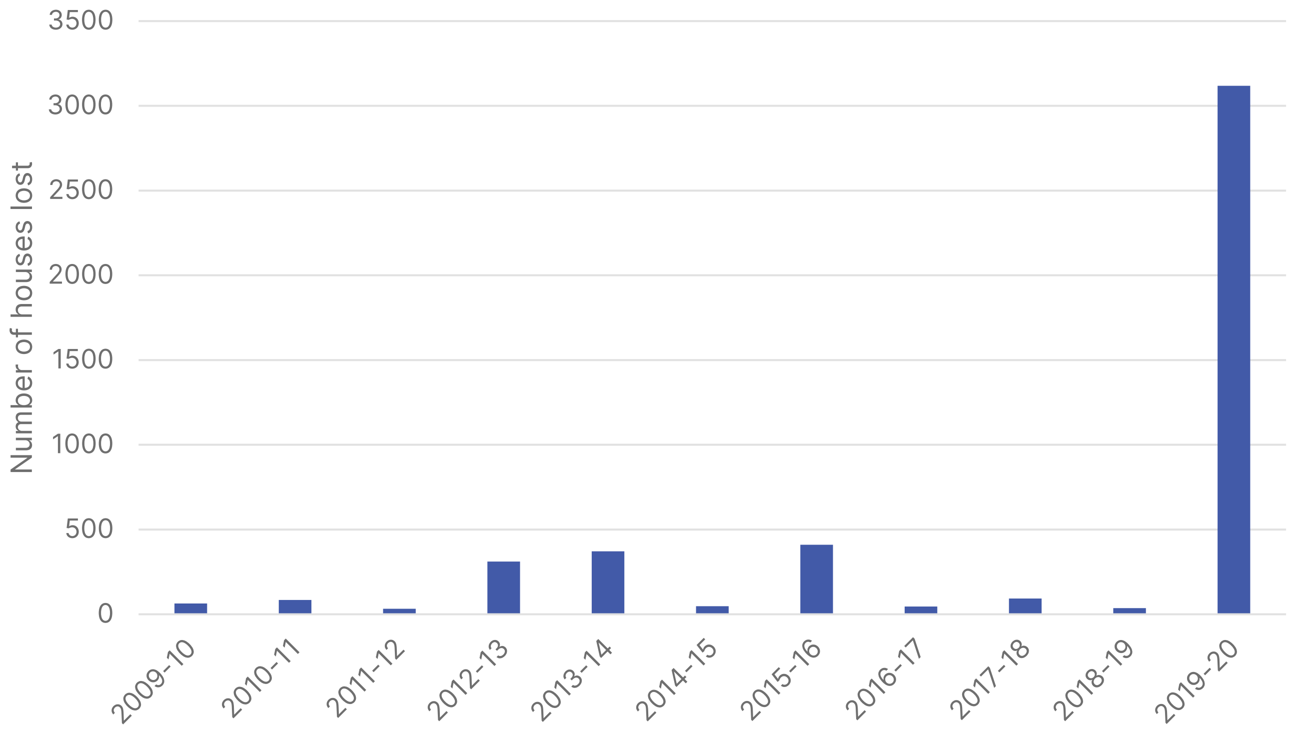


Figure C.2 Approximate number of fatalities resulting from bushfires in Australia 2009 to 2020

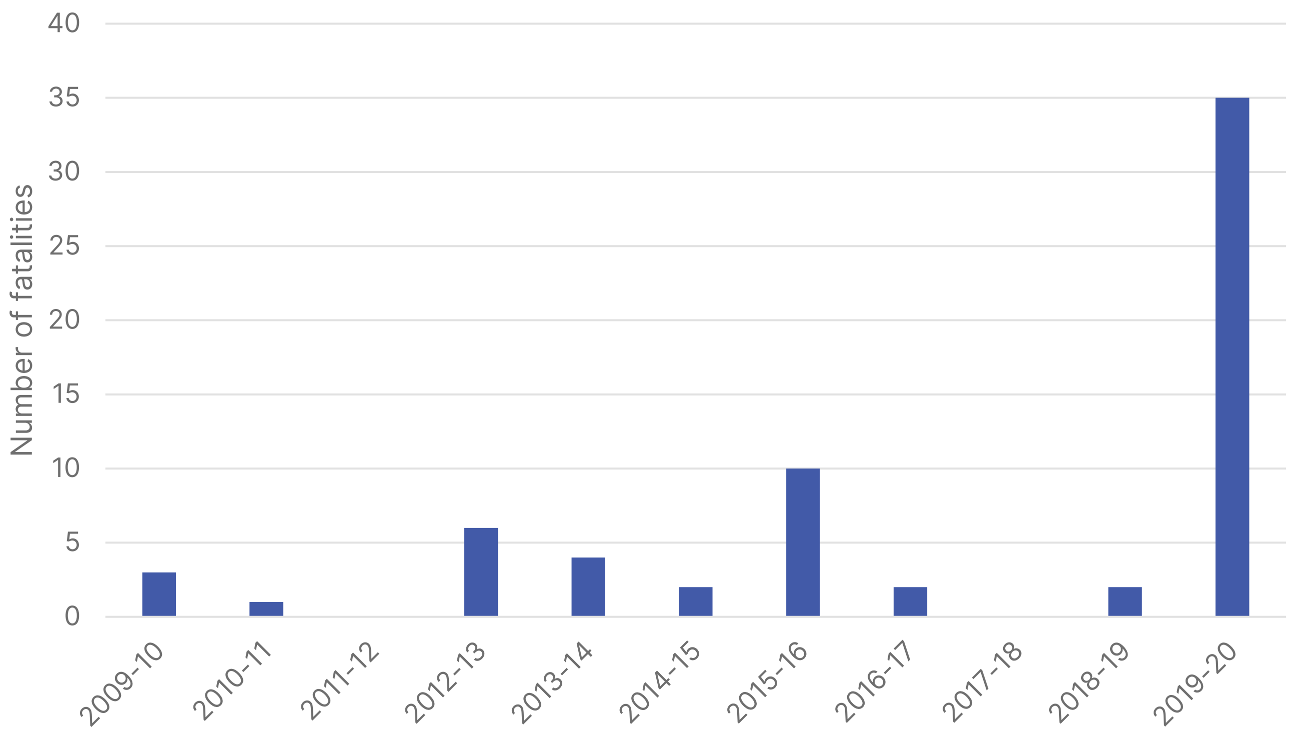


Figure C.3 Approximate house losses by state or territory 2009 to 2020

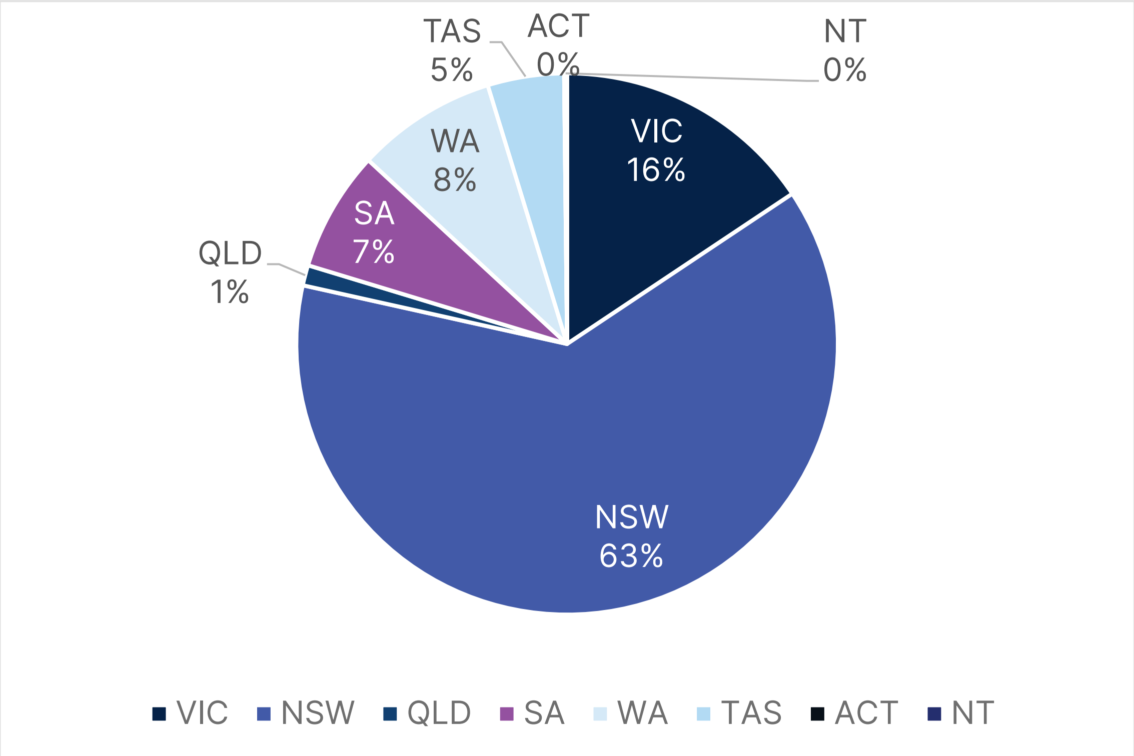
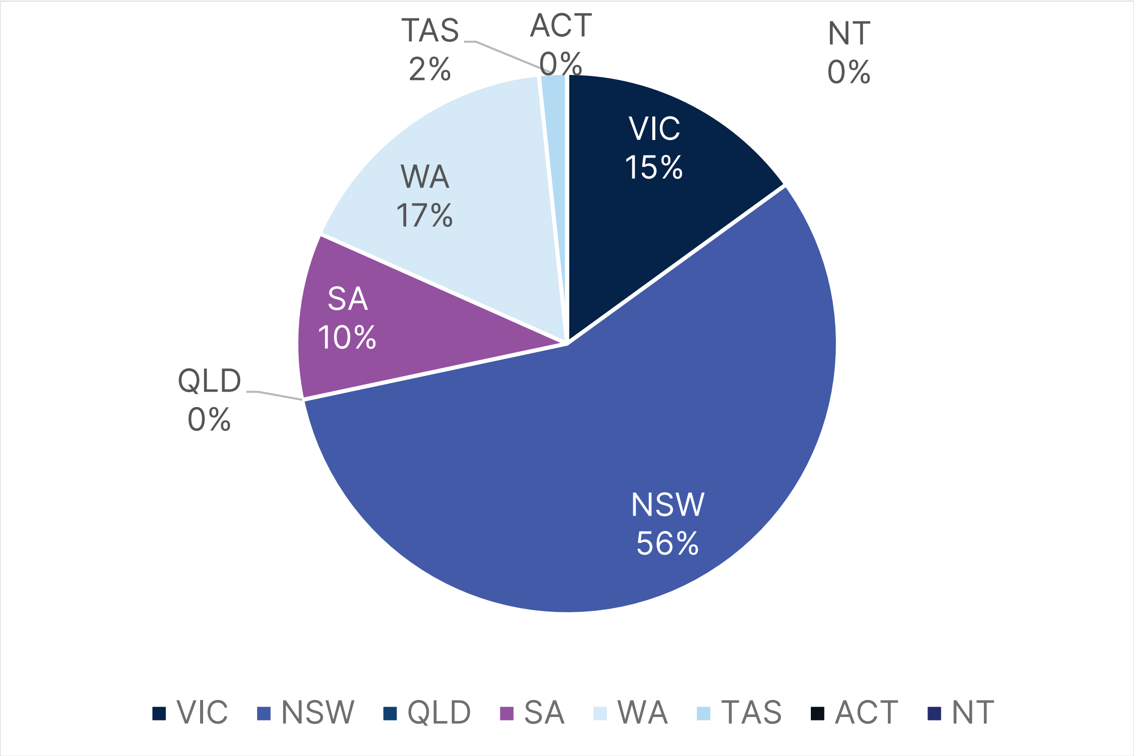


Figure C.4 Approximate life loss by state or territory 2009 to 2020



Appendix D Defined terms

D.1 NCC defined terms

NCC definitions are contained in Schedule 1 of NCC 2022 Volumes One, Two and Three.

Some of the NCC defined terms used frequently in this handbook are defined below for convenience, with additional explanatory information where appropriate.

Designated bushfire prone area is land which has been designated under a power of legislation as being subject, or likely to be subject, to bushfires.

Design bushfire is the characteristics of a bushfire, its initiation, spread and development, which arises from weather conditions, topography and fuel (vegetation) in a given setting, used to determine fire actions.

Alert:

If the Verification Method **simple** analysis options are applied, the design bushfire is determined based predominantly on the APE for design fire weather conditions in conjunction with the topography and vegetation. It is also assumed that a worse credible bushfire occurs and spreads to the subject property interface at the same time as the design fire weather conditions occur.

If the Verification Method **complex analysis** options are applied an APE is specified with respect to the occurrence of a design bushfire which in addition to fire weather, topography and vegetation; takes into account the probability of fire ignition, development and spread to the subject property interface.

Fire actions are each of the following:

(a) airborne embers; and
(b) burning debris and/or accumulated embers adjacent to building elements; and
(c) heat transfer from combustible materials within the site; and
(d) radiant heat from a bushfire front; and
(e) flame contact from a bushfire front; and
(f) the period of time post fire front subject to collapsing vegetation due to persistent combustion.

Site is the part of the allotment of land on which a building stands or is to be erected.

D.2 Other terms

Annual Probability of Exceedance (APE) or Annual Exceedance Probability (AEP) is the probability that an event (e.g. bushfire or weather conditions) of a greater severity or magnitude will occur within a period of 1 year.

Building ignition is for the purpose of interpreting G5V1 and H7V2 is the occurrence of sustained combustion or fire ignition within the building. This clarifies that ignition of parts of the external facade of a building is permitted provided that flaming combustion is not sustained to the extent that the evacuation of occupants is compromised, or fire spread to the building interior occurs.

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.

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