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Issue 5	10 Jan 19	Paul England	Final Report addressing ABCB Comments
Issue 6	21 Jan 19	Paul England	Modifications to Executive Summary and Conclusions to improve clarity

Authorisation by:

J P England

Date: 21 January 2019

General Conditions of Use

EXECUTIVE SUMMARY

A quantified risk assessment has been undertaken on behalf of the Australian Building Codes Board (ABCB) relating to the risk to vulnerable occupants in Class 9 Buildings Associated with Bushfire Attack in designated Bushfire Prone Areas based on, amongst other things:

- Historical data of losses of dwellings and people
- Application of the current NCC 2016 Deemed-to-Satisfy provisions applicable to the relevant building types (including Amendment 1)
- Consideration of the impact of State and territory variations / approval and referral mechanisms

The Vulnerable Occupants Groups considered in this study were;

- The occupants and patients in a Class 9a health-care building
- Students in a Primary or Secondary School
- Children in an Early childcare centre
- Residents in an Aged Care building

It was found that vulnerable people are exposed to significantly higher risks than the general population during a bushfire event. It may not be practicable to prohibit construction of Class 9 buildings housing vulnerable occupants in bushfire prone areas but in some cases, this could be a valid and reasonable solution which would be generally managed through the planning process. Where existing communities need to be served by schools and health-care facilities and locating these services at substantial distances away from communities may increase other risks such as transport risks and health risks due to delayed treatments in addition to disadvantaging the local communities, construction of Class 9 buildings housing vulnerable occupants within Bushfire Prone Areas may be required. Early evacuation strategies may be appropriate and the preferred option for some Class 9 buildings such as schools.

Given the above, the following proposed performance requirement for Class 9 buildings housing vulnerable occupants was developed.

GP5.2 Draft

A Class 9 building housing vulnerable occupants that may be used as a refuge for the vulnerable occupants (and other people) that is constructed in a designated bushfire prone area must, to the degree necessary—

(a) be designed and constructed to reduce the risk of ignition from a bushfire, appropriate to the—

(i) potential for ignition caused by burning embers, radiant heat or flame generated by a bushfire; and

(ii) intensity of the bushfire attack on the building; and

(b) be provided with vehicular access to the site to assist firefighting and emergency personnel defend the building or evacuate occupants; and

(c) be provided with access at all times to a sufficient supply of water for firefighting purposes on the site.

(d) provide a tenable environment for occupants during the passage of external untenable conditions arising from a bushfire event, appropriate to the –

i. location of the refuge relative to fire hazards including-
    aa) predominant vegetation; and
    bb) adjacent buildings, structures and movable objects; and
    cc) car parking area/s and allotment boundaries; and

dd) other combustible materials;

ii. number of occupants to be accommodated within the refuge, and
iii. duration of occupancy, and
iv. bushfire intensity having regard to the bushfire attack level; and
v. intensity of potential consequential fires, and
vi. safe access within the site to the refuge, (including carpark areas), as well as occupant egress after the bushfire event; and
vii. occupant tenability within the refuge for the duration of occupancy before, during and after the bushfire event; and
viii. combined effects of structural, fire exposure and actions to which the refuge may reasonably be subjected; and
ix. provision of fire-fighting equipment and water supply to facilitate protection of the refuge

The Verification Method GV5 to be included in NCC 2019, only applies to Class 2 and 3 buildings, and it will require some adjustment if it is to be applied to the draft GP5.2 presented above.

A proposed prescriptive solution, which may be developed into Deemed-to-Satisfy Provisions, was derived from the Design and Construction of Community Bushfire Refuges Handbook criteria with modifications appropriate to an occupied Class 9 building as determined in this report. The proposed prescriptive solution is summarised below:

Parameter	**Enhanced Provisions - Community Bushfire Refuge requirements**
Separation from all classified vegetation	Radiant heat flux exposure not exceeding 10kW/m^2
Separation between buildings	12m minimum or; FRL of 60/60/60 and any openings suitably protected or; radiant heat flux not exceeding 10kW/m^2
Separation distance from allotment boundaries	10 m minimum, or; FRL of 60/60/60 and any openings suitably protected, or; radiant heat flux not exceeding 10 kW/m^2.
Separation distance from car parking areas	10 m minimum, or; FRL of 60/60/60 and with any openings suitably protected, or; radiant heat flux not exceeding 10 kW/m^2.
Separation distance to other hazards e.g. gas bottles / medical gas storage etc.	Appropriate measures for risk; Full fire separation appropriate to the hazard (but not less than FRL 60/60/60) or separation distance to maintain heat flux not exceeding 10kW/m^2 from all sources (acting simultaneously)
Provision of non-combustible paths around building	1.5 m wide around the perimeter of the building.
Maximum permitted radiant heat flux from bushfire on exposed building elements	10 kW/m^2
Special access provisions to buildings	Access pathways should be readily identifiable and have a relatively even surface with a minimum clear width of 1m
External areas where occupants may be exposed to radiant heat flux from fire front	Maximum incident radiant heat flux from the fire front not greater than 1 kW/m^2. (above the background solar radiant heat).

Parameter	Enhanced Provisions - Community Bushfire Refuge requirements
Internal tenability through duration of occupancy	A mechanical air-handling system must be provided to maintain adequate air quality and temperatures. Typically, the air handling system should be capable of: • being adjusted for full recycling of air for limited periods to avoid the introduction of smoke and • maintaining internal air temperatures below 25°C If the air conditioning fails -the design of the building envelope should • maintain max internal air temperatures below 39°C and • limit maximum internal surface temperatures to 60°C As far as practicable, the internal building space should be split into two or more sub-compartments on each level with each sub-compartment served by independent mechanical air-handling systems to allow for occupants to be moved to an airconditioned area if an air conditioning unit fails. The system design should account for activation of smoke detectors from low concentrations of smoke from external sources to ensure that the air conditioning and other essential services can remain operational.
External Envelope	The external envelop shall be non-combustible and comply with the AS 3959 construction requirements for BAL 19 or greater. Resistance to wind loads and collapsing trees shall be addressed as part of the structural design
Alarm System Control	Operational policies should be established to silence the alarm system if activated by smoke of a bushfire close to the building. This may require additional features to be provided for the detection systems within the building. The design and procedures should be developed in conjunction with the designers, fire authorities and relevant authorities.
Signage and Fire Safety Plan	Signage should provide warning occupants not to store combustible materials under buildings or adjacent to buildings and the bushfire safety plan for the building should be documented in a manual and provided to the building owners and operators.

Parameter	Enhanced Provisions - Community Bushfire Refuge requirements
Vehicular Access	Access roads shall be designed, constructed and maintained to a standard not less than a Modified 4C Access Road. A Modified 4C Access Road is an all-weather road which complies with the Australian Road Research Board "Unsealed Road Manual -Guidelines to good practice",3rd Edition, March 2009 as a classification 4C Access Road and the following modified requirements: Single lane private access roads less than 6 m carriageway width must have20m long passing bays of 6 m carriageway width, not more than 100m apart; A private access road longer than 100 m, must be provided with a driveway encircling the building or a hammerhead "T" or "Y" with a turning head 4 m wide and 8 m long, or a trafficable circular turning area of 10 m radius; Culverts and bridges must be designed for a minimum vehicle load of 20 tonnes; and Vegetation must be cleared for a height of 4 m, above the carriageway, and 2 m each side of the carriageway.
External manual firefighting provisions	Coverage of the perimeter of the refuge for a distance of 10m perpendicular to the perimeter shall be provided with a non-combustible water tank connected to a pump with sufficient back-up power / fuel to supply water to hose reels. Water tank capacity and backup power / fuel supplies should be determined by the appropriate fire authority
Emergency Power Supply	Diesel powered generator and associated fuel storage should be provided. Generator capacity should be determined by the appropriate authority. Diesel fuel storage capacity and location to be determined by the appropriate authority.

A Quantitative Risk Assessment was undertaken using event trees with supporting data from various bushfire investigations, tests, and analyses on which to estimate the inputs. The results were compared against the acceptance criterion of a 10% probability of ignition as specified by NCC 2019 Verification Method GV5.

This acceptance criterion was applied to a scenario with manual suppression since the building will be occupied and provisions for firefighting are provided. The probability of ignition for this scenario was estimated to be approximately 1%. Therefore, the acceptance criterion was satisfied with a safety factor of an order of magnitude (1% compared to the acceptance criteria of 10%). This is considered appropriate having regard for the vulnerability of occupants, community sensitivity to societal risk involving large loss of life and limited available data on which to base estimates for some probabilities, notwithstanding the adoption of a 1 in 200 Annual Probability of Exceedance (APE) weather conditions.

Separation distances and protection from other buildings have been addressed by the above provisions for Class 9 buildings containing vulnerable occupants and therefore it is reasonable for buildings that will not be occupied during a bushfire event, to be protected in accordance with the NCC’s less stringent requirements that currently apply to Class 2 and 3 buildings if the building does not provide critical services to occupied Class 9 buildings and does not serve other critical community functions.

CONTENTS

1. Overview and Interpretations

1.1. Introduction

The Australian Building Codes Board (ABCB) is undertaking a project relating to the risk to vulnerable occupants in Class 9 Buildings associated with bushfire attack in designated Bushfire Prone Areas;

Vulnerable Occupants considered in this report include;

- The occupants and patients in a Class 9a health-care building
- Students in a Primary or Secondary School
- Children in an Early child-care centre
- Residents in an Aged Care building

A quantified risk assessment is to be undertaken based on, amongst other things:

- Historical data of losses of dwellings and people
- Application of the current NCC 2016 Deemed-to-Satisfy provisions applicable to the relevant building types (including Amendment 1)
- Consideration of the impact of State and territory variations / approval and referral mechanisms

The National Construction Code Volume 1(NCC)[1] Part A0 specifies procedures for evaluation of performance solutions and these procedures have been adapted to undertake this project. The risk assessment approach used for this project is outlined in Figure 1.

The first stage of this project was the development of a preliminary report which was submitted to the ABCB for feedback and comment before undertaken the detailed analysis; serving an equivalent role to the Fire Engineering Brief Process described in the Fire Engineering Guidelines 2005[2].

The content of this report is summarised below:

Section 1 Provides an Overview of the study being undertaken, and a glossary of terms used.

A review of the current NCC requirements and typical State legislation that have relevance to this project is provided in Section 2.

Other ABCB Publications and reports relevant to this Study are discussed in Section 3

A Hazard Identification Process is documented in Section 4 which includes a characterisation of the vulnerable occupants and identification of areas / populations exposed to significant risk from Bushfires. Potential Mitigation options were derived for further consideration.

The process of Scenario Development and a preliminary Qualitative Risk Assessment is described in Section 5 using the NFPA 550 Fire Safety Concepts Tree [3] to provide structure and objectivity to the qualitative analysis. The outcomes were used to select and refine appropriate mitigation measures for further analysis and a brief overview of the proposed detailed analysis to further verify the proposed building solutions was provided.

Section 6 Presents the detailed analysis that was undertaken with additional supporting information included in Appendices.

Conclusions are presented in Section 7

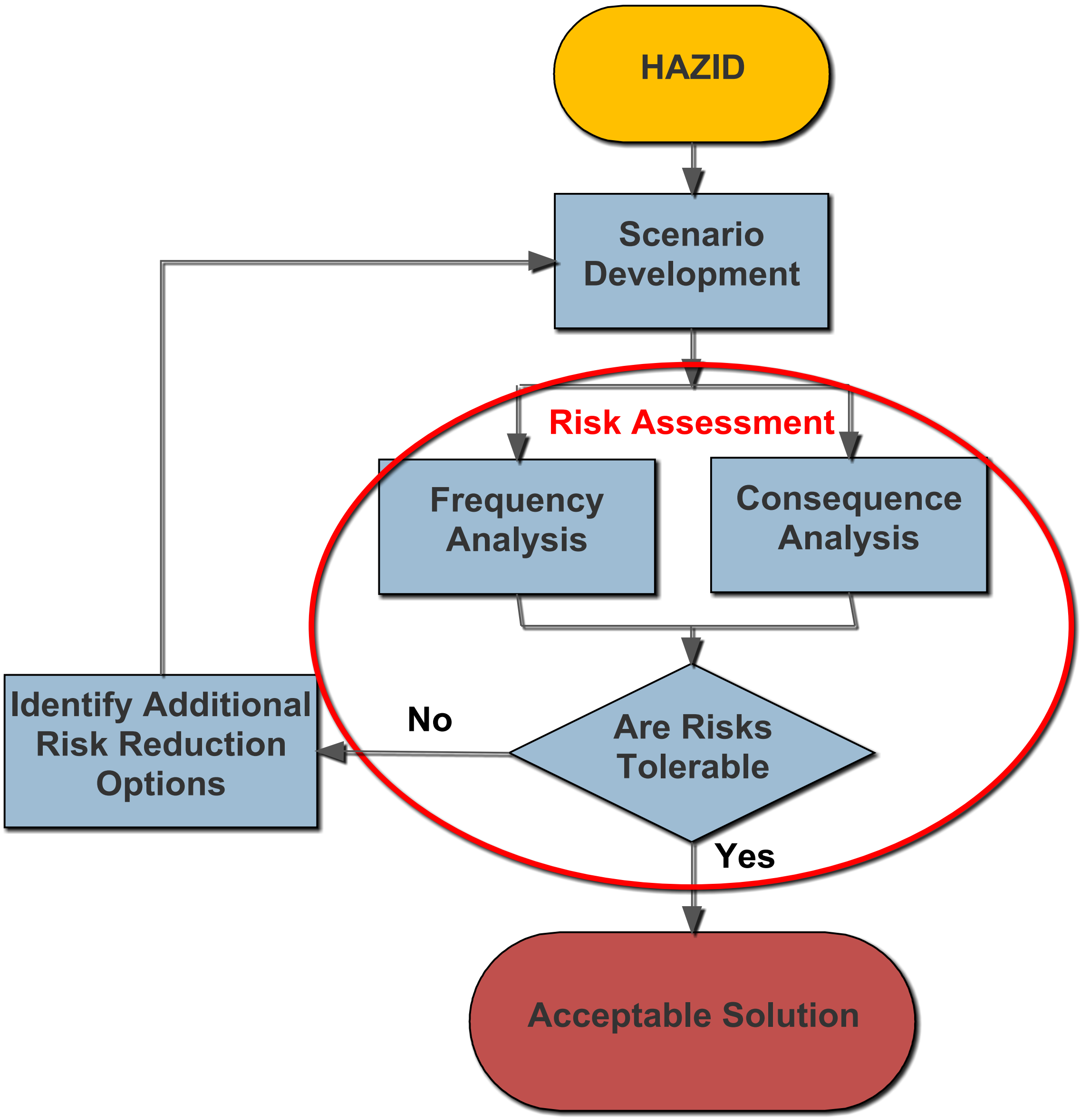


Figure 1 Risk Assessment Method

1.2. Glossary of Terms

Building Envelope means the roof, exterior walls and floor of a structure that form a barrier that separates the interior of the building from the outdoor environment

Bushfire is an unplanned fire burning in vegetation;

Bushfire Attack Level (BAL) indicates the potential severity of a building's exposure to ember attack, radiant heat and direct flame contact. It is the basis for establishing the requirements for construction under AS 3959-2009 [4] . The following six Bushfire Attack Levels are defined in AS 3959 as follows:

BAL-LOW The risk is considered to be VERY LOW. There is insufficient risk to warrant any specific construction requirements but there is still some risk.
BAL-12.5 The risk is considered to be LOW. There is a risk of ember attack. The construction elements are expected to be exposed to a heat flux not greater than 12.5 kW/m^2.

BAL-19 The risk is considered to be MODERATE. There is a risk of ember attack and burning debris ignited by wind borne embers and a likelihood of exposure to radiant heat.
The construction elements are expected to be exposed to a heat flux not greater than 19 kW/m^2.
BAL-29 The risk is considered to be HIGH. There is an increased risk of ember attack and burning debris ignited by windborne embers and a likelihood of exposure to an increased level of radiant heat. The construction elements are expected to be exposed to a heat flux not greater than 29 kW/m^2.
BAL-40 The risk is considered to be VERY HIGH. There is an increased risk of ember attack and burning debris ignited by windborne embers, a likelihood of exposure to a high level of radiant heat and some likelihood of direct exposure to flames from the fire front.
The construction elements are expected to be exposed to a heat flux not greater than 40 kW/m^2.
BAL-FZ The risk is considered to be EXTREME. There is an extremely high risk of ember attack and burning debris ignited by windborne embers, and a likelihood of exposure to an extreme level of radiant heat and direct exposure to flames from the fire front.
The construction elements are expected to be exposed to a heat flux greater than 40 kW/m^2.
BALs are measured in increments of radiant heat (expressed in kW/m^2).

Classified vegetation means vegetation that may presents a significant bush fire risk and has been classified in accordance with AS 3959 to determine the Bushfire Attack Level. AS 3939 Classes of vegetation include;

- Forest,
- Woodland,
- Shrubland,
- Scrub,
- Mallee / Mulga,
- Rainforest,
- Grassland,
- Tussock Moorland

Designated Bushfire Prone Area or Bushfire Prone Area means land which has been designated under a power of legislation as being subject, or likely to be subject, to bushfires.

Drought Factor is a measure of the dryness of forest fuels; its calculation is based on the amount of rain needed to fully saturate the soil and the amount of recent rainfall.

Fire Danger Rating - is based on a Fire Danger Index value (equivalent to the FFDI) and is used to effectively define the fire hazard and provide appropriate advice to the community. The Fire Danger Rating was derived by the AEMC - National Bushfire Warnings Taskforce [5] and is summarised in Table 1 together with recommended actions for the general population:

Forest Fire Danger Index (FFDI) is a measure the degree of danger of fire in Australian forests and is a function of the drought factor), wind speed, temperature and humidity.

Low Threat Vegetation (based on the AS3959 definition) is generally vegetation that is excluded from a BAL assessment undertaken in accordance with AS 3959 and typically includes:

- Small isolated areas of vegetation
- Non-vegetated areas, including waterways, exposed beaches, roads, footpaths, buildings and rocky outcrops.
- Vegetation regarded as low threat due to factors such as flammability, moisture content or fuel load including

- grassland managed in a minimal fuel condition,
- mangroves and other saline wetlands, maintained lawns,
- maintained public reserves and parklands,
- cultivated gardens,
- nature strips and windbreaks.

Refer AS 3959 [4] for futher detail.

Table 1 Fire Danger Rating Criteria

Fire Danger Rating	Description
CATASTROPHIC FDI 100+ (Code Red)	• Fires will be uncontrollable, unpredictable and fast moving – flames will be higher than roof tops. • People will die and be injured. Thousands of homes and businesses will be destroyed. • Well prepared, well-constructed and defended homes may not be safe during the fire. Construction standards do not go beyond a Fire Danger Index of 100. • Thousands of embers will be blown around. • Spot fires will move quickly and come from many directions, up to 20 km ahead of the fire. **Leaving is the best option.**
EXTREME FDI 75-99	• Fires will be uncontrollable, unpredictable and fast moving – flames will be higher than roof tops. • People will die and be injured. Hundreds of homes and businesses will be destroyed. • Only well prepared, well constructed and actively defended houses are likely to offer safety during a fire. • Thousands of embers will be blown around. • Spot fires will move quickly and come from many directions, up to 6 km ahead of the fire. **Leaving is the safest option for your survival.**
SEVERE FDI 50-74	• Fires will be uncontrollable and move quickly– flames may be higher than roof tops. • There is a chance people may die and be injured. Some homes and businesses will be destroyed. • Well prepared and actively defended houses can offer safety during a fire. • Expect embers to be blown around. • Spot fires may occur up to 4 km ahead of the fire **Leaving is the safest option for your survival. Your home will only offer safety if it and you are well prepared and you can actively defend it during a fire.**
VERY HIGH FDI 25-49	• Fires can be difficult to control – flames may burn into the tree tops. • There is a low chance people may die or be injured. Some homes and businesses may be damaged or destroyed. • Well prepared and actively defended houses can offer safety during a fire. • Embers may be blown ahead of the fire. • Spot fires may occur up to 2 km ahead of the fire. **Leaving is the safest option for your survival. Your home will only offer safety if it is and you are well prepared, and you can actively defend it during a fire.**

Fire Danger Rating	Description
HIGH FDI 12-24	• Fires can be controlled • Loss of life is highly unlikely and damage to property will be limited • Well prepared and actively defended houses can offer safety during a fire. • Embers may be blown ahead of the fire. • Spot fires can occur close to the main fire. **Know where to get more information and monitor the situation for any changes**
LOW-MODERATE FDI 0-11	• Fires can be easily controlled • Little to no risk to life and property **Know where to get more information and monitor the situation for any changes**

Special fire protection purpose (as per Section 100B (6) of the Rural Fires Act 1997) means any of the following purposes:

(a) a school,
(b) a child care centre,
(c) a hospital (including a hospital for the mentally ill or mentally disordered),
(d) a hotel, motel or other tourist accommodation,
(e) a building wholly or principally used as a home or other establishment for mentally incapacitated persons,
(f) seniors housing within the meaning of State Environmental Planning Policy (Housing for Seniors or People with a Disability) 2004,
(g) a group home within the meaning of State Environmental Planning Policy No 9 Group Homes (now SEPP (Affordable Rental Housing) 2009),
(h) a retirement village,
(i) any other purpose prescribed by the regulations (Rural Fires Regulation 2013).

Note: For application of this definition in the BCA, the term "school" does not include a college, university or similar tertiary educational establishment.

Specific use bushfire protected building (as defined in the Victorian Building Regulations 2018) means—

(a) a Class 9a or 9c building; or
(b) a building from which a school within the meaning of section 1.1.3(1) of the Education and Training Reform Act 2006 is operated; or
(c) a building from which an early childhood centre is operated; or
(d) a Class 4 part of a building associated with a building referred to in paragraphs (a) to (c); or
(e) a Class 10a building or deck associated with a building referred to in paragraphs (a) to (c)

Vulnerable land use (as defined in WA Planning Policy) means a land use where persons may be less able to respond in a bushfire emergency.

1.3. Changes to Reference Documents

1.3.1. National Construction Code Edition 2019

The analysis presented in this report has been undertaken with reference to Standards and Codes that were current at the start of the project (10 September 2018) unless specifically noted in the report.

The relevant edition of the National Construction Code current at the time of preparation of this report was NCC 2016 Volume 1 (Ammendment 1) [6] this is to be superceded by the NCC 2019 Volume 1[7] due for publication in February 2019 and adoption in May 2019.

Through this project drafts of a Bushfire Verification Method (GV5) were provided including a final version that is expected to be included in the 2019 edition. A copy of this final draft is included in Appendix B of this report.

During the project new editions of critical NCC reference documents were published which will be referenced in the NCC 2019 edition. Key references are considered in the following sub-sections.

1.3.2. AS 3959:2018 Construction of Buildings in Bushfire-Prone Areas

AS 3959:2018 Construction of Buildings in Bushfire-Prone Areas [8] will supercede AS 3959-2009 [4]. The preface to the 2018 edition identified that the revision incorporated the following changes:

(a) The site assessment in Section 2 has been simplified to address interpretational issues related to slope, grasslands and low threat vegetation.

(b) Section 3 clarifies that the shielding concessions relate only to the elements of the wall and do not apply to the subfloor or roofs.

(c) The protection of gaps and openings has been by requiring suitable measures for doors and windows and providing for other gaps to be suitably sealed.

(d) The requirements for floors at BAL-12.5 and BAL-19 re1ating to bearers, joists and flooring within 400 mm above finished groud level now align with BAL-29.

(e) Windows address the framed material, hardware, glazing, seals and weather strips and screens. Doors address the door panel material door frame material, hardware, glazing, seals and weather proofing, screens and to be tight fitting. Vehicle access doors recognise that guide tracks do not permit direct access for embers and do not require edge gap protection. Weather strips are to conform with a flammability index of no greater than five (AS 1530.2)

f) Roofs can now include certain translucent or transparent roof coverings at BAL-12.5 and BAL-19 for verandas, carports or awnings where the roof is separated from the main building.

(g) Editorial changes have been made for consistency with Section 2 and to locate tables with the relevant sections; of the site assessment methodology. Appendices F and H have been combined.

In addition AS 3959:2018 referenced a new timber crib size (AA) to be used for determining BAL ratings for elements of construction by test in accordance with a new edition of a secondary reference AS 1530.8.1[9] also published in late 2018.

The above modifications to AS 3959 are not expecte to significantly impact on the findings of this report since they generally relate to refinements of the 2009 edition reflecting the experience using the standard rather than major changes.

2. NCC Requirements and Related Legislation

2.1. General NCC Requirements for the Construction of Class 9 buildings in Bushfire Prone Areas

Performance requirement GP 5.1 from the NCC [6] is reproduced below and identifies Classes of buildings to which the performance requirement applies:

“**GP5.1**

A building that is constructed in a designated bushfire prone area must, to the degree necessary, be designed and constructed to reduce the risk of ignition from a bushfire, appropriate to the—

(a) potential for ignition caused by burning embers, radiant heat or flame generated by a bushfire; and
(b) intensity of the bushfire attack on the building.

Application

GP5.1 only applies to—
(a) a Class 2 or 3 building; or
(b) a Class 10a building or deck associated with a Class 2 or 3 building, located in a designated bushfire prone area. “

Since Class 9 buildings are not nominated in the application of GP5.1 and it is the only performance requirement within Part G of the NCC [3] it is concluded that there are no specific requirements generally applicable in all States and Territories relating to the Construction of Class 9 buildings in Bushfire Prone Areas. (Refer Section 2.2 for State Variations and Regulations that nominate requirements for Class 9 buildings)

This is confirmed in Clause G5.1 which similarly applies the deemed-to-satisfy requirements for construction in Bushfire Prone Areas only to Class 2,3 and a Class 10a deck or building associated with Class 2 or 3 buildings.

2.2. State and Territory Variations

Any variations to the NCC requirements are expected to be included in the State and Territory Appendices but the NCC requirements can be modified by means of State Legislation. The following sub sections highlight some of the most relevant variations

2.2.1. NSW

A NSW Appendix modifies the Application Clause in GP5.1 as detailed below:

Application:

NSW GP5.1 only applies in a designated bushfire prone area, to—

(a) a Class 2 or 3 building;
(b) a Class 4 part of a building;
(c) a Class 9 building that is a special fire protection purpose; or
(d) a Class 10a building or deck associated with a building or part referred to in (a), (b) or (c).

The definition of special fire protection purpose buildings includes Class 9 buildings housing vulnerable people.

The NCC deemed-to-satisfy provisions are for construction in Bushfire Prone Areas are also modified as detailed below:

NSW G5.2 Protection

In a designated bushfire prone area, a Class 2 building, a Class3 building, a Class 4 part of a building or a Class 9 building that is a special fire protection purpose or a Class 10a building or deck associated with such a building or part, must comply with the following—

(a) AS 3959 except for Section 9 Construction for Bushfire Attack Level FZ (BAL-FZ). Buildings subject to BAL-FZ must comply with specific conditions of development consent for construction at this level; or
(b) the requirements of (a) above as modified by the development consent following consultation with the NSW Rural Fire Service under section 79BA of the Environmental Planning and Assessment Act 1979; or
(c) the requirements of (a) above as modified by development consent with a bushfire safety authority issued under section 100B of the Rural Fires Act 1997 for the purposes of integrated development

Therefore, the NSW NCC Appendix requires Class 9 Special Fire Protection Purpose Buildings (which house vulnerable occupants) to be constructed in accordance with the same requirements that apply to Class 2 and 3 buildings. It is noted that the Deemed-to-Satisfy Solutions for buildings in close proximity to a bushfire hazard (BAL FZ) may be subject to additional specific conditions of development.

2.2.2. Queensland

The Queensland Appendix includes some minor relaxations with respect to the application of the NCC requirements particularly in rainforest areas but does not introduce requirements for Class 9 buildings.

2.2.3. Tasmania

The Tasmanian Appendix does not introduce specific requirements for Class 9 buildings, but it adds requirements for vehicular access and water supplies for Class 2,3 and 10a buildings.

However, the Tasmanian Building Regulations 2016[10] include the following provisions that expand the scope of the NCC.
"64. Bushfire-prone areas and National Construction Code

(1) For the purposes of the National Construction Code –
(a) a bushfire-prone area is designated as being subject, or likely to be subject, to bushfires; and
(b) a bushfire-prone area is a designated bushfire-prone area.

(2) For the purposes of the Act, a building in a bushfire-prone area is taken to comply with the performance requirements of GP5.1 or P2.3.4 of the National Construction Code if the building meets relevant performance requirements set out in the bushfire determination.

(3) For the purposes of the Act, a building in a bushfire-prone area is taken to comply with the deemed-to-satisfy provisions for GP5.1 or P2.3.4 of the National Construction Code if the building meets the relevant deemed-to-satisfy provisions set out in the bushfire determination.

(4) For the purposes of the Act, the performance requirements of GP5.1 of the National Construction Code apply to all classes of buildings, and work performed in a bushfire-prone area, to which this Part applies.

(5) The following provisions of the National Construction Code do not apply to a building, or work, that meets the requirements of this regulation:

(a) G5.0, G5.1 and G5.2 of, and Tas Part G5 of the Tasmanian appendix to, Volume One;
(b) Part 3.7.4 of Volume Two"

Of particular relevance to this study are;

Subclause (4) which applies the performance requirements in GP5.1 to all Classes of Building

Subclause (5) which indicates that the requirements of G5.0, G5.1 and G5.2 of, and Tas Part G5 of the Tasmanian appendix do not apply to a building that meets the regulations and

Subclause (2) which states for the purposes of the Act, a building in a bushfire-prone area is taken to comply with the performance requirements of GP5.1 or P2.3.4 of the National Construction Code if the building meets relevant performance requirements set out in the bushfire determination.

Director's Determination – Requirements for Building in Bushfire-Prone Areas issued in August 2017[11] applies amongst other things to Class 9 buildings and contains the following performance requirements:

"3. Performance Requirements

(1) A building to which this Determination applies must, to the degree necessary, be:

(a) Designed and constructed to reduce the ignition from bushfire, appropriate to the –

(i) Potential for ignition caused by burning embers, radiant heat or flame generated by bushfire; and

(ii) Intensity of the bushfire attack on the building;

(b) Provided with vehicular access to the site to assist fire-fighting and emergency personnel to defend the building or evacuate occupants;

(c) Provided with access at all times to a sufficient supply of water for firefighting purposes on the site; and

(d) Provided with appropriate separation of the building from the bushfire hazard.

(2) The performance requirement specified in subclause (1)(a) is applicable to the following:

(a) a Class 1, 2 or 3 building; or

(b) a Class 10a building or deck associated with a Class 1, 2 or 3 building"

Sub clause (2) of Section 3 of the determination appears to exclude the building construction performance requirements for Class 9 buildings but retain requirements for vehicular access, water supply and appropriate separation from the bushfire hazard to maintain BAL exposure no greater than BAL 12.5 or equivalent risk if the building is classified as vulnerable use as defined in the Bushfire Prone Area Code (Planning Directive 5.1)[12]

The Planning Directive 5.1 defines a vulnerable use as meaning

(a) Custodial Facility;

(b) Educational and Occasional Care;

(c) Hospital Services;

(d) Residential if for respite centre, residential aged care home, retirement home, and group home.

The combined effect is to limit the exposure to the BAL 12.5 level for Class 9 buildings housing vulnerable occupants unless a bushfire hazard management plan provides, to the degree necessary, separation of the building from the bushfire hazard, appropriate resistance to ignition from bushfire, property access and water supply for firefighting.

It is also noted that the Director's Determination – Requirements for Building in Bushfire-Prone Areas issued in August 2017 indicates that where BAL 40 or BAL FZ is assessed for Class 2 and 3 buildings, the Performance Requirements are stated not to be satisfied by complying with the Deemed-to-Satisfy Requirements of the NCC

2.2.4. South Australia

The South Australian Appendix does not introduce specific requirements for Class 9 buildings, but it modifies site assessment / classification procedures for lower risk areas and includes tables modifying the prescribed construction solutions in AS3959.

2.2.5. Victoria

Although not included in the Victorian Appendix of the NCC; the Building Regulations 2018[13] in effect vary the requirements of the NCC as detailed in the extract below relating to Specific use bushfire protected buildings.

158 Specific use bushfire protected buildings—construction requirements

(1) The BCA Volume One applies as if in clause A1.1, after the definition of **Sole-occupancy unit** there were inserted—

"**Specific use bushfire protected building** means—

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

(b) a building from which a school within the meaning of section 1.1.3(1) of the **Education and Training Reform Act 2006** is operated; or

(c) a building from which an *early childhood centre* is operated; or

(d) a Class 4 part of a building associated with a building referred to in paragraphs (a) to (c); or

(e) a Class 10a building or deck associated with a building referred to in paragraphs (a) to (c).".

(2) The BCA Volume One applies as if in Part G5—

(a) in the **Application** at the foot of clause GP5.1, there were inserted after paragraph (a)—

"(ab) a *specific use bushfire protected building*; or";

(b) in clause G5.1, there were inserted after paragraph (a)—

"(ab) a *specific use bushfire protected building*; or";

(c) in clause G5.2, there were inserted after paragraph (a)—

"(ab) *a specific use bushfire protected building*; or".

This change has the effect of applying performance requirement GP5.1 to Class 9 buildings housing vulnerable people and allowing the use of the NCC Deemed-to-Satisfy Solutions for Class 2 and 3 buildings to also be applied to Class 9 buildings housing vulnerable occupants.

2.2.6. Western Australia

The State Planning Policy 3.7 Planning in Bushfire Prone Areas [14] indicates that applications for vulnerable or high-risk land uses in areas where BAL-12.5 to BAL-29 applies will not be supported unless they are accompanied by a Bushfire Management Plan jointly endorsed by the relevant local government and the State authority for emergency services. In areas where BAL-40 or BAL-Flame Zone (FZ) applies Subdivision and development applications for vulnerable or high-risk land uses will not be supported unless development is unavoidable.

Vulnerable land use is defined as a land use where persons may be less able to respond in a bushfire emergency.

Examples of what constitutes a vulnerable land use are provided in the Guideline for Planning in Bushfire Prone Areas[15]. The Guideline indicates typically, vulnerable land uses are those where persons may be less able to respond in a bushfire emergency. These can be categorised as land uses and associated infrastructure that are designed to accommodate groups of people with reduced physical or mental ability such as the elderly, children (under 18 years of age), and the sick or injured in dedicated facilities such as aged or assisted care, nursing homes, education centres, family day care centres, child care centres, hospitals and rehabilitation centres amongst other things.

This example aligns with the project scope of Class 9 buildings housing vulnerable occupants

2.3. Summary of Application of NCC to Class 9 Buildings Housing Vulnerable Occupants

Based on the above review, the Bushfire requirements of Part G5 of the NCC (including reference to AS 3959:2009) are commonly applied in full or in part to Class 9 buildings housing vulnerable occupants through various building and or planning regulatory paths.

Implementation varies from specification of compliance with the same requirements that are applied to Class 2 and 3 buildings in Victoria to use of the BAL assessment methods only to determine if development should be permitted. In some instances, performance-based approaches are mandated particularly for higher BAL ratings.

It is therefore apparent that there is no nationally consistent approach to the treatment of Class 9 Buildings housing vulnerable people in Bushfire Prone Areas.

The Productivity Commission Research Report - Reform of Building Regulation [16] included the following observations regarding the benefits of a national approach including the preferred approach when dealing with the application of specific requirements for areas subjected to natural hazards rather than applying State variations.

“National consistency is desirable for a number of reasons. Builders and designers, especially those that operate across jurisdictional borders, can use and apply a single set of mandatory requirements, rather than having to be familiar with multiple codes. Further, building designs that comply in one jurisdiction do not have to be reworked or altered to comply in other jurisdictions. This is especially useful for

owners or users of buildings, such as wholesalers and retailers, who wish to use the same design for multiple buildings across jurisdictions. Manufacturers of building products strongly support a national scheme, as this allows them to manufacture a single product to meet demand across all jurisdictions, rather than having to develop different products for each jurisdiction. Tradespeople benefit from consistent building designs as they can apply their skills in any jurisdiction. The development of a national code is also likely to be significantly more cost effective for government than developing eight separate State and Territory based codes.

Within the framework of a national code, the BCA caters for the specific needs of geographic areas. For instance, the Code applies specific requirements for protection against storms in areas likely to be subject to cyclones. This gives the code sufficient flexibility, without resorting to variation according to jurisdictional borders. A national code, with uniform requirements according to geographic/climatic needs, is superior to uniformity within each State"

The advantages of a nationally consistent approach was taken into account when deriving options for further evaluation

3. Other Relevant ABCB Publications

3.1. NCC Bushfire Verification Method and Handbook

Verification Methods GV5 and V2.7.2. are proposed to be included in the 2019 edition of the NCC. The latest draft of proposed verification method GV5 available at the time of preparation is included in Appendix B

The Class 9a and Class 9c buildings considered in this study fall within Importance Level 4. Although not specifically listed, Class 9b buildings used for students in a Primary or Secondary School or Children in an Early child-care centre would also fall into importance Class 4 if a defend in place strategy is adopted.

A handbook is also being developed to provide guidance to practitioners seeking to demonstrate compliance with the Verification Methods GV5 and V2.7.2. which addresses the design process in generic terms but does not prescribe specific design methods or inputs. This report has drawn on information within a draft of the handbook[17] where appropriate.

3.2. NCC Design and Construction of Community Bushfire Refuges Handbook

The ABCB published a handbook for the Design and Construction of Community Bushfire Refuges[18] in 2014 which will have relevance to this study if defend-in-place strategies are applicable to Class 9 buildings housing vulnerable occupants.

Whilst the handbook is a non-mandatory document it follows the same general format of the NCC by specifying objectives, functional statements and performance criteria as detailed below:

Objective: The objective of the Handbook is to facilitate temporary shelter for people who could not safely defend their property or evacuate the local area prior to the passage of a bushfire event and have no safer place to shelter.

Functional Statement: A structure designed for emergency occupation during a bushfire event must provide shelter to occupants from the direct and indirect actions of a bushfire.

Performance Criteria: A community bushfire refuge must be designed and constructed to provide a tenable environment for occupants during the passage of untenable conditions arising from a bushfire event, appropriate to the –

(a) location of the refuge relative to fire hazards including-

(i) predominant vegetation; and
(ii) adjacent buildings, structures and movable objects; and
(iii) car parking area/s and allotment boundaries; and
(iv) other combustible materials;

(b) number of occupants to be accommodated within the refuge, and
(c) duration of occupancy, and
(d) bushfire intensity having regard to the bushfire attack level; and
(e) intensity of potential consequential fires, and
(f) safe access within the site to the refuge, (including carpark areas), as well as occupant egress after the bushfire event; and
(g) occupant tenability within the refuge for the duration of occupancy before, during and after the bushfire event; and
(h) generation of smoke, heat and toxic gases from materials used to construct the refuge; and
(i) combined effects of structural and fire loads and actions to which the refuge may reasonably be subjected; and
(j) necessary degree of occupant awareness of external conditions; and
(k) provision of fire-fighting equipment and water supply to facilitate protection of the refuge; and
(l) necessary degree of communications and signage; and
(m) necessary degree of sanitary and other facilities required for all occupants; and
(n) necessary degree of essential maintenance.

In addition, acceptance criteria were also specified which are included in Appendix A

The role of a community bushfire refuge and related performance and acceptance criteria are closely aligned to the needs of a class 9 building housing vulnerable occupants if a defend in place strategy is adopted in lieu of an early evacuation strategy and therefore the criteria for increased protection levels, if required will be derived from these existing criteria to provide a consistent approach within the NCC and related documents.

4. Hazard ID

4.1. Characterisation of Vulnerable Occupants in Class 9 Buildings

4.1.1. Characterisation Criteria

When considering the impact of internal building fires, it is usually sufficient to consider an assembly point at a sufficient distance from the building as a place of safety during an evacuation and in some cases protected locations may be provided within a building as part of a defend in place / progressive evacuation strategy.

Bushfires present a different type of hazard in that the external environment outside a building may not be a place of safety and even if the bushfire is not immediately threatening a building external smoke levels may be hazardous particularly with respect to vulnerable occupants.

Therefore, when considering evacuation of vulnerable people during a bushfire emergency the evacuation process needs to address early relocation to appropriate alternative locations and the safety of the occupants whilst in transit.

A useful characterisation of occupants (clients) has been developed by the Department of Human Services relating to health-care facilities provided or supported by the department[19]. Whilst it applies to evacuation from a specific building and not necessarily relocation the characterisation has been adapted for the risk assessment of vulnerable occupants in Bushfire Prone Areas (Bennetts et al [20])

The characterisation identifies six types of clients (occupants) as detailed below:

Ambulant (Type 1)

A *client* who is able to understand and respond to an alarm and able to independently evacuate without staff present in the building.

Ambulant (Type 2)

A *client,* who is able to understand and respond to an alarm, can evacuate with staff intervention or can evacuate independently with a delay. For example, staff implement the evacuation plan including providing verbal instructions, coordination, supervision and limited physical assistance, such as hand or arm holding.

Ambulant (Type 3)

A *client* who is not able to understand and respond to an alarm but, can evacuate with staff intervention. For example, staff implement the evacuation plan including providing verbal instructions, coordination, supervision and limited physical assistance, such as hand or arm holding.

Non-ambulant (Type 4)

A *client* who is able to understand and respond to an alarm but, may not be able to evacuate independently or, will take extra time to evacuate independently. They will require verbal instructions and substantial physical assistance from staff to evacuate. For example, removal from bed and placement in a wheelchair, stretcher.

Non-ambulant (Type 5)

A *client* who is not able to understand or respond to an alarm and not able to evacuate without physical assistance. The *client* will require verbal instructions and substantial physical assistance from staff to evacuate. For example, removal from bed and placement in a wheelchair or stretcher.

Non-ambulant (Type 6)

A *client* who cannot be evacuated (i.e. on life support or similar).

If an early (non-emergency) evacuation and relocation strategy is being considered the risk to life during the evacuation and relocation and resources necessary to undertake a safe evacuation need to be assessed and compared to the risks associated with a defend in place strategy.

The Victorian Residential Aged Care Services Bushfire Ready Resource [21] provides advice to service providers for planning and preparedness for potential bushfires. Included is information required to plan for evacuation and relocation including occupant (client) types used by the ambulance services for non-emergency patient transport from which Table 2 has been derived for supplementary consideration of the practicality of evacuation / relocation options.

Table 2 Client Evacuation Capability Types for Non-emergency Patient Transport

Type	Description
Walker patient:	• Is able to ambulate with or without the use of a mobility device and able to successfully transfer into a seat in a vehicle • Is able to climb two small steps into a minibus (with or without assistance) • Is able to travel comfortably in a seated position • Has no requirement for administration by the crew of pain relief, intervening treatment, monitoring, IV therapy, O2, or clinical observations whilst in transit • Does not require transportation for psychiatric treatment.
Walker assist patient	• Can be pushed in a wheelchair and able to successfully transfer into a seat in a vehicle • Is able to travel comfortably in a seated position • Does not require transportation for psychiatric treatment
Hoist patient	• Has no requirement for administration by the crew of pain relief, intervening treatment, monitoring, IV therapy, O2, or clinical observations while in transit • Is confined to and is able to travel comfortably in a wheelchair for the duration of the journey; and • Is unable to transfer into a seat in a vehicle • Does not require transportation for psychiatric treatment. • Note: A hoist patient travels in a wheelchair that is 'locked down' into a dedicated restraint system.
Stretcher patient:	• A patient who requires transport in a recumbent or semi-recumbent position and/or requires treatment, monitoring, observation or supervision during transport. • In all cases an assessment has been made by a medical practitioner that the • patient is hemodynamically stable for the duration of the transport and there is no likelihood that the patient will require transport under emergency conditions • The health professional is required to provide the patient acuity details (low, medium or high), consistent with the Non-emergency patient transport clinical practice protocols.

Low-acuity patient	• The patient has no emergency clinical symptoms or signs of recent onset
	• The patient has an illness or injury that does not require active treatment, but which does require supervised patient transport. Examples include:
	    o inability to travel in a normal seated position
	    o requirement for oxygen during transport
	    o impaired cognitive function
	    o inability to travel more than a few steps unaided.

Type	Description
Medium acuity patient	• The patient does not meet the criteria of an emergency patient • There is an illness or injury which requires one or more of the following: ○ cardiac monitoring ○ observation and monitoring of an intravenous infusion of a crystalloid fluid, with or without an infusion pump ○ observation and monitoring of an intravenous infusion of crystalloid fluid containing glyceryl trinitrate or heparin using (an) infusion pump(s) ○ care of an intercostal catheter or central venous catheter ○ care of the patient who has a recent fracture of the spinal column (without spinal cord injury) ○ care of the patient on home ventilation. • Medium-acuity status also applies if the patient has a mental illness and is assessed as behaviourally stable by the sending practitioner. • Patients on home ventilation are regarded as medium-acuity patients, provided that the NEPT attendant or a carer is able to perform: ○ tracheal suctioning ○ connection of the ventilator to the tracheostomy in the event of accidental disconnection (if the patient is unable to do this) ○ connection of a bag or valve device (such as Ambu bag) to the tracheostomy for the administration of ventilation in the event that the ventilator fails.
High-acuity patient	• The patient does not meet the criteria of an emergency patient. • There is an illness or injury that requires active monitoring or treatment by a nurse or medical practitioner, including: ○ mechanical ventilation ○ an intravenous infusion of a vasoactive drug ○ a patient with tracheostomy ○ a patient with a central or arterial line ○ a device that supports circulation (intra-aortic balloon pump or extra-corporeal ○ membrane oxygenation)

4.1.2. Occupants of Class 9a Health-Care Buildings

The DHS Fire Risk Management Guidelines – Hospitals[22] indicates that a hospital can house clients (occupants) of any Type from 1 to 6. The mix of occupants may vary between facilities but there are likely to be cases where full evacuation and relocation of a hospital buildings is impractical.

It is also likely that that the vulnerability of occupants to exposure to smoke and heat will be greater than for the general population and any firefighting activities will need to be undertaken by staff and / or external capabilities.

For clients (occupants) that can be safely evacuated there is likely to be a mix of the evacuation capability types listed in Table 2 with ambulances or similar specialised transport being required for significant numbers of patients.

4.1.3. Occupants of Class 9b Primary and Secondary Schools

The Tasmanian SEMC Policy Statement - Emergency Management Framework for Vulnerable People [23] includes a useful summary of risk factors and special consideration for children which is summarised below:

“Children can behave unpredictably in response to stressful situations or may be overwhelmed because of their level of physical, cognitive and emotional development. Typical vulnerabilities include the following:

- Lack the ability to independently access transportation assistance and services.
- May become separated from family and caregivers.
- May not have an appropriate level of understanding of the threat.
- Susceptible to injury and depend on others for livelihood, decision-making and emotional support.
- May suffer greater harm from exposure to smoke or chemical agents because of their size, metabolisms, respiratory rates and other factors.
- More likely to develop dehydration, malnutrition and exhaustion quicker than adults and more susceptible to infectious diseases and severe forms of illness.
- Treatments that would be adequate for adults might be inappropriate for children e.g. children need different medication doses and medical equipment sizes to adults. Water pressure used to decontaminate adults may be inappropriate for young children.
- May have additional health care or medication needs but are unable to communicate those needs

Typical mitigation measures that should be considered include the following:

- Evacuation centres will require trained staff.
- May require personal support from care provider.
- May require assistance with daily living activities.
- May require communication support from parent or care provider.
- Supervisory needs must be addressed.
- Facilities serving children must have plans that meet the needs of the children they serve.
- Mental health needs of children must be addressed separately from adults.”

Depending on the age of students the occupant characteristics correlate to Ambulant Type 1 to 3 and the applicable evacuation capability type from Table 2 would be Walker but with a need for supervision. The ratio of the number of children to supervisors necessary for orderly and safe evacuation would tend to increase as the age of the children increases. Specialised vehicles such as ambulances would not be required for evacuation in most situations

4.1.4. Occupants of Class 9b Early Childhood Centres

A study undertaken into the prevalence and fire safety implications of early childhood centres by Page and Norman[24] summarised the findings of Taciuc and Dederichs[25] based on surveys with 87 responses (62 teachers and 25 fire experts) from USA, Germany, Denmark, Romania, and Canada as follows:

- Between 30 and 36 months, children are generally capable of understanding and following simple fire evacuation instructions.
- Between 24 and 30 months, they can generally walk down stairs.
- Younger than 24 months, they can evacuate horizontally without assistance (unless they are toddlers or babies).

- Teachers say that between 24- and 30-months children will not become upset by unusual events (e.g. fire and emergency evacuation).
- Learning is very age-specific, and pre-schoolers remember images (e.g. of a lighter) but not the accompanying safety message.
- The child-adult ratio varies significantly. For children under two, the median is four in the USA and Denmark, and six in Germany. For children between 24 and 30 months, the median ratios are four in the USA and Denmark, and eight in Germany. For children older than 30 months, the median is ten in the USA and Germany, and five in Denmark.
- Almost 50% of teachers said they could carry one or two children in an evacuation. The rest would hold a children's hands to assist evacuation.

Depending on the age of students the occupant characteristics correlate to Ambulant Type 3 or Non-ambulant Type 4 and the applicable evacuation capability type from Table 2 would be "Walker" or "Walker Assist" but with a need for supervision and assistance. The ratio of children to supervisors necessary for orderly evacuation would tend to increase as the age of the children increases. Below 30 months the adult to child ratio is typically 1:4. Specialised vehicles such as ambulances would not necessarily be required for evacuation

4.1.5. Occupants of Class 9c Aged-Care Facility

Aged-Care facilities can be classified as Class 3, Class 9a or Class 9c buildings depending on the capability of the occupants. The potential exists for clients of varying care needs to be accommodated in the same building and Class 9c was developed to address a mix of low and high care occupants to facilitate aging in place, amongst other things

It therefore follows that the occupants of a Class 9c building may comprise a mix of evacuation capabilities varying from Type 1 to 5. The mix of occupants may vary between facilities but there are likely to be cases where full evacuation and relocation of Class 9c aged-care accommodation buildings is impractical.

The vulnerability of aged occupants to exposure to smoke and heat is greater than the general population and any firefighting activities will need to be undertaken by staff and / or external resources (e.g. fire brigade).

Ambulances or similar specialised transport would be required for significant numbers of occupants and there could be significant risk to life from the evacuation process for the most vulnerable occupants. This was demonstrated during the Black Saturday fires where two aged-care facilities in the Bunyip area were evacuated. The evacuations were not undertaken prior to bushfires approaching the surrounding area and appropriate vehicles were not available for all the occupants. There were 82 occupied beds in the facilities at the time of the fire most of which could be considered to be highly vulnerable. Four occupants of the aged-care facilities died in the ensuing days and it was stated in evidence to the Royal Commission[26] that the deaths could be attributed to the disruption and shock of evacuation.

4.2. Bushfire Hazard

4.2.1. Availability of Bushfire Data

Reported losses of Class 9 buildings resulting from Bushfires are rare and therefore it has been necessary to rely predominately on house loss and general bushfire fatality data to quantify bushfire hazards. The following sections review this data.

4.2.2. Distribution of Life Loss for Australia

The majority of life loss from bushfires (over 60%) has occurred in Victoria and the combination of Victoria (61%) NSW (17%) South Australia (7%) and Tasmania (8%) make up 93% of the loss of life

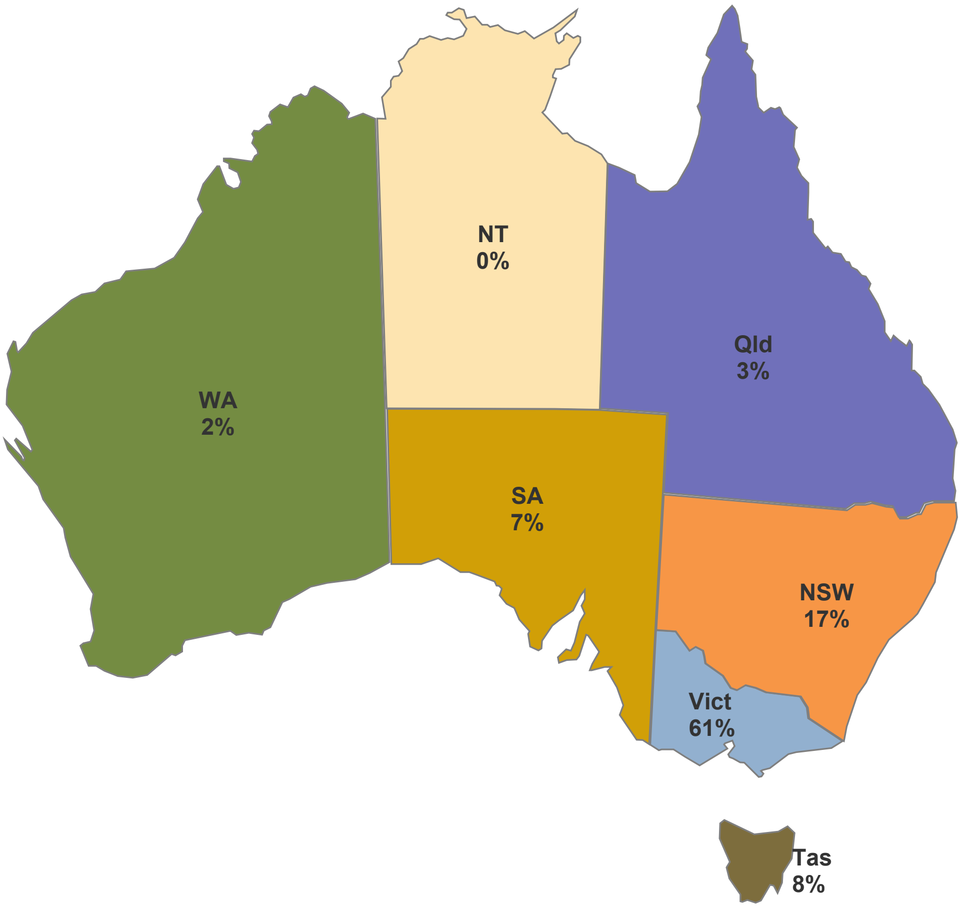
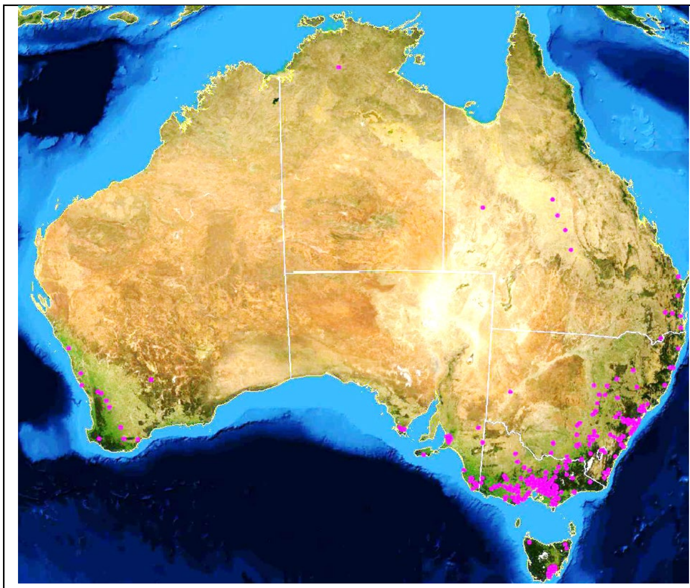
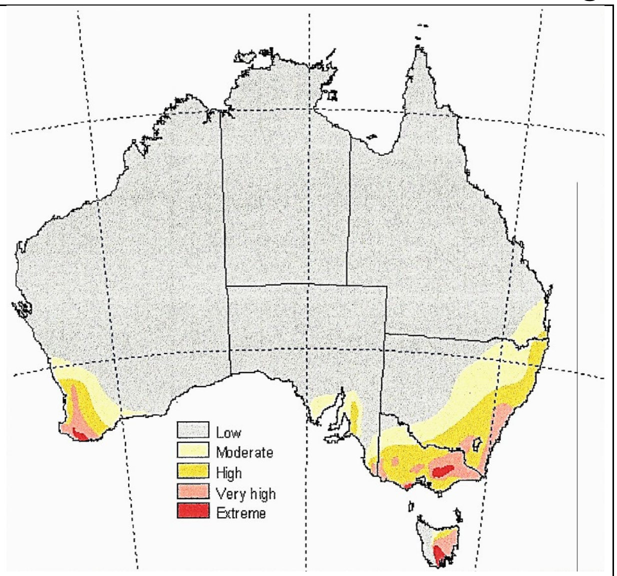


Figure 2 Life Loss from Bushfires 1901-2011 based on Blanchi 2012[27]

A plot of the location of life loss during fires was also included in Blanchi et al [27] and has been compared to a plot of the comparative bushfire risk from an insurance perspective from Blong [28] in Figure 3



Blanchi 2012 Location of all fatalities in Australia (background map from Google Earth)



Bushfire Risk Estimates from Blong 2000

Figure 3 Comparison of Bushfire Fatalities plotted by Blanchi[27] against Bushfire Risk Estimates from Blong [28]

The data shows that the Bushfire Risk varies considerably across Australia with substantial proportions of residents in Victoria and Tasmania and small proportions of the southern parts of NSW, South Australia and Western Australia being exposed to a very high risk relative to other areas.

4.2.3. Approximate Estimate of the Individual Risk for Occupants of Buildings

The Life and House Loss Database provides a dataset containing bushfire related life loss in Australia for the period 1901-2011 and was described by Blanchi[27]

The report identifies that over the 110-year period 260 bushfires have been associated with a total of 825 known civilian and firefighter fatalities. However only a proportion of these fatalities were associated with buildings. The following information was reported by Blanchi[27] based on the database:

Table 3 Fatal Bushfire Exposure Locations

Exposure location	Fatalities between 1901-1964	Fatalities between 1965-2011	Fatalities between 1901-2011
Inside structure	21	167(44%)	188
Inside vehicle	11	45 (12%)	56
Open air	232	158 (42%)	390
Unknown	34	6 (2%)	40
Total	298	376	674

The cumulative % fatalities based on distance to the forest where reported for 137 of the 188 fatalities identified as occurring in structures and are summarised in Table 4:

Table 4 Cumulative fatalities within Structures based on distance from forest

Distance from forest	Cumulative fatalities
10m	76%
30m	88%
50m	95%

The NCC regulates buildings within 100m of the predominant vegetation and therefore it is appropriate to estimate the individual risk for the population within 100m of the threat. Chen and McAneney[29] estimated that for all addresses in major capital cities and surrounding areas that approximately 6% are within 100m of bushland.

Using the most recent period 1965-2011 there were 167 fatalities within structures during the 46-year period (approximately 3.6 fatalities / year).

The average population of Australia for the period 1965 to 2011 was approximately 16,571,500 based on ABS data[30]

Assuming 6% of the population are exposed to Bushfire Hazard, an average of 994,290 people were potentially exposed to the bushfire hazard each year between 1965 to 2011 yielding an average individual risk of fatality within a building located within 100m from bushland per annum of approximately 3.6 x 10^{-6}.

4.2.4. Historic Societal Risks

Based on the above individual risk level it could be argued that the risk is tolerable without applying significant additional controls such as AS 3959[4] construction requirements since the risk level is comparable with those for other situations generally accepted by the community such as house fires from causes other than bushfires.

However, the historic record of bushfires in Australia includes a number of severe fire seasons, particularly in the State of Victoria, where high numbers of fatalities and house losses have occurred over a short time frame having a severe impact on the local communities.

Sometimes these losses result from several fires started independently that impact on a number of communities at the urban interface at different times, but these independent events tend to be perceived by the community as one larger event and the losses aggregated. When considering, what is a tolerable societal risk on a national basis, it is therefore appropriate to group losses occurring over a similar time frame and geographic location together as a single event. Table 5 is a summary of major bushfire incidents from the life and house loss database reported by Blanchi et al but with the Black Friday fires classified as a single event over 3 days and the Ash Wednesday fires classified as a single event despite losses in both Victoria and South Australia. The database does not capture all bushfire loss data but does provide a reasonable sample covering 733 civilian fatalities.

Table 5 Major Fire Loss Consolidated Events derived from Blanchi et al

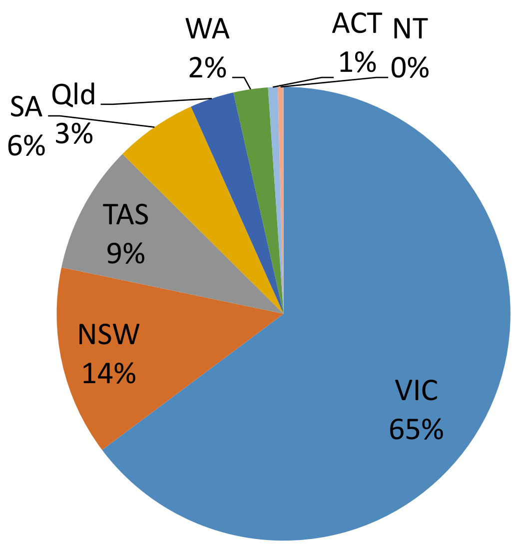
Date of Fire	Description	State	Civilian Fatalities	House Losses
14-February-1926	Black Sunday Gippsland	VIC	31	550
10-13-January 1939	Black Friday fires	VIC	66	650
14 January 1944	Linton	VIC	48	700
14 February 1944	Morwell			
7 February 1967	Black - Tuesday Hobart	TAS	64	1257
8 January 1969	Lara	VIC	20	230
16 February 1983	Ash Wednesday	VIC	46	2060
		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.

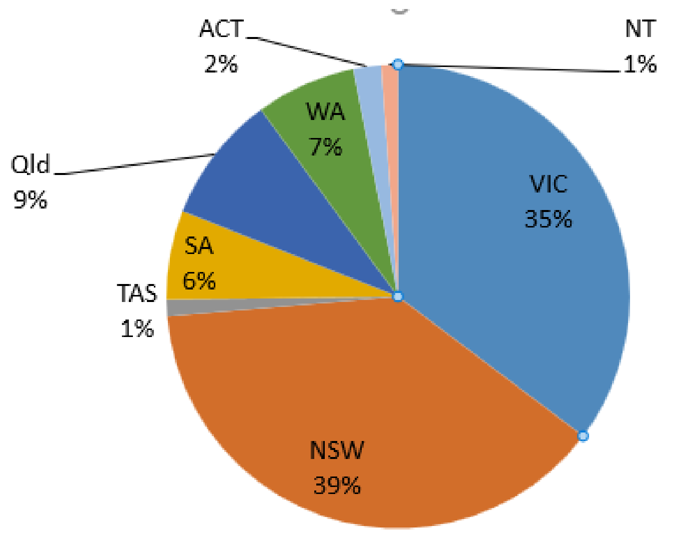
Some key observations from Table 5 are;

- fatalities varied from 20 to 172 per consolidated incident.
- the eight consolidated events represent approximately 65% of the civilian fatalities directly attributable to bushfires.
- the eight major losses impacted three States and occurred in Victoria in seven of the eight consolidated events and over 80% of the fatalities in these major incidents occurred in Victoria.

The higher proportion of losses in Victoria is also reflected in the total number of fatalities. Blanchi identified that over 60% of all fatalities in the life and house loss database occurred in Victoria as noted previously. However, if the eight major consolidated events listed in Table 5 are excluded the distribution changes significantly as can be observed by examination of Figure 4.



All bushfires



All bushfires excluding eight consolidated events

Figure 4 Total Civilian Fatality Geographic Distribution derived from Blanchi [27]

Therefore, based on the above analysis when considering benchmarks for regulation, the focus will tend to be on societal risk and the mitigation of the impact of major high loss events.

Australian aggregated fatalities for bushfires normalized to 2008 values (to take into account variations in the population exposed to bushfire risks) for the period from 1925-2009 have been reported by Crompton [31]. Honert [32] observed that after normalising the data there was a downward trend in fatalities of 0.1761 falalities/annum and therefore the losses may be conservative (overestimated) since improved mitigation measures and communication systems were not in place at the start of the sample period. Notwithstanding this observation the normalised data is considered to provide the most appropriate indication of the societal risk and the results after normalisation are shown as a FN-plot in Figure 5.

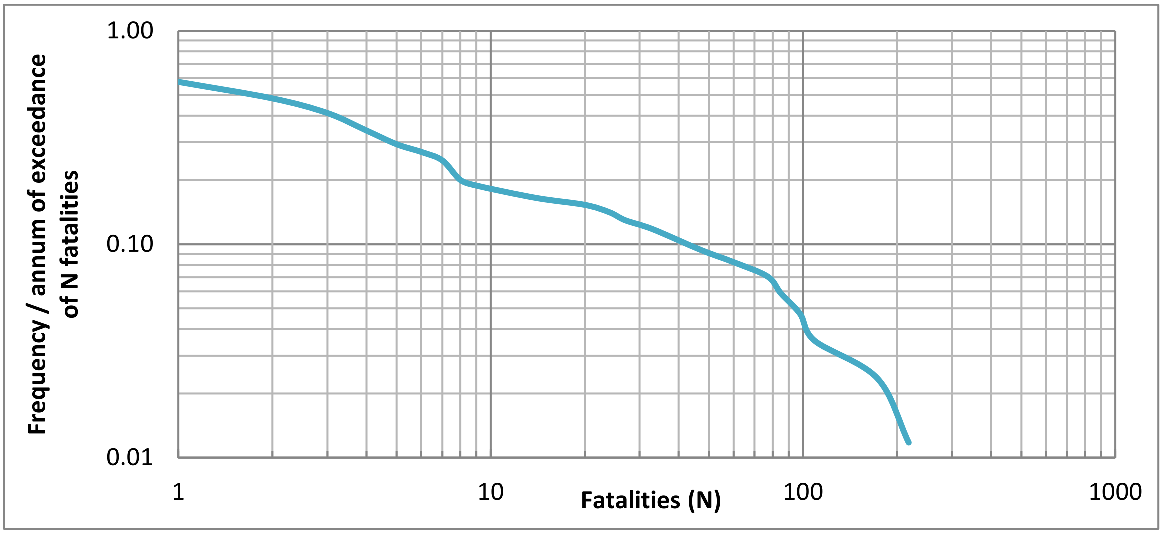


Figure 5 FN Plot of Australian Bushfire Losses based on fatalities normalised for population to 2008 values from Crompton [31]

Blanchi [27] plotted the number of fatalities against the FFDI Index at 3pm from bushfires recorded in the Life and House Loss Database. The plot is shown in Figure 6 with fatality categories added.

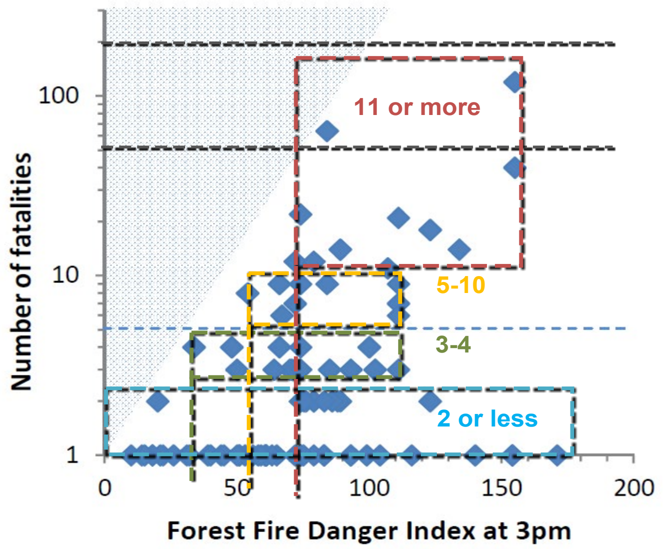


Figure 6 Relationships between the number of fatalities and FFDI at 3pm adapted from Blanchi with fatality categories added.

Typically, societal risks are considered for 10 or more fatalities from a single incident. The FFDI threshold for 5-10 fatalities based on historic events is approximately 55 and for 11 and above fatalities is approximately 75.

4.2.5. Distribution of House Loss for Australia by State and Territory

Blanchi [33] reported the location of house losses by State for the period from 1939-2006 based on the data available which followed the same general trend as life loss with over 55% losses in Victoria (this would increase if Black Saturday fires from 2009 were included) NSW approx. 20%, Tasmania approx. 16% and SA approx. 6% with relatively small losses in WA, NT and QLD.

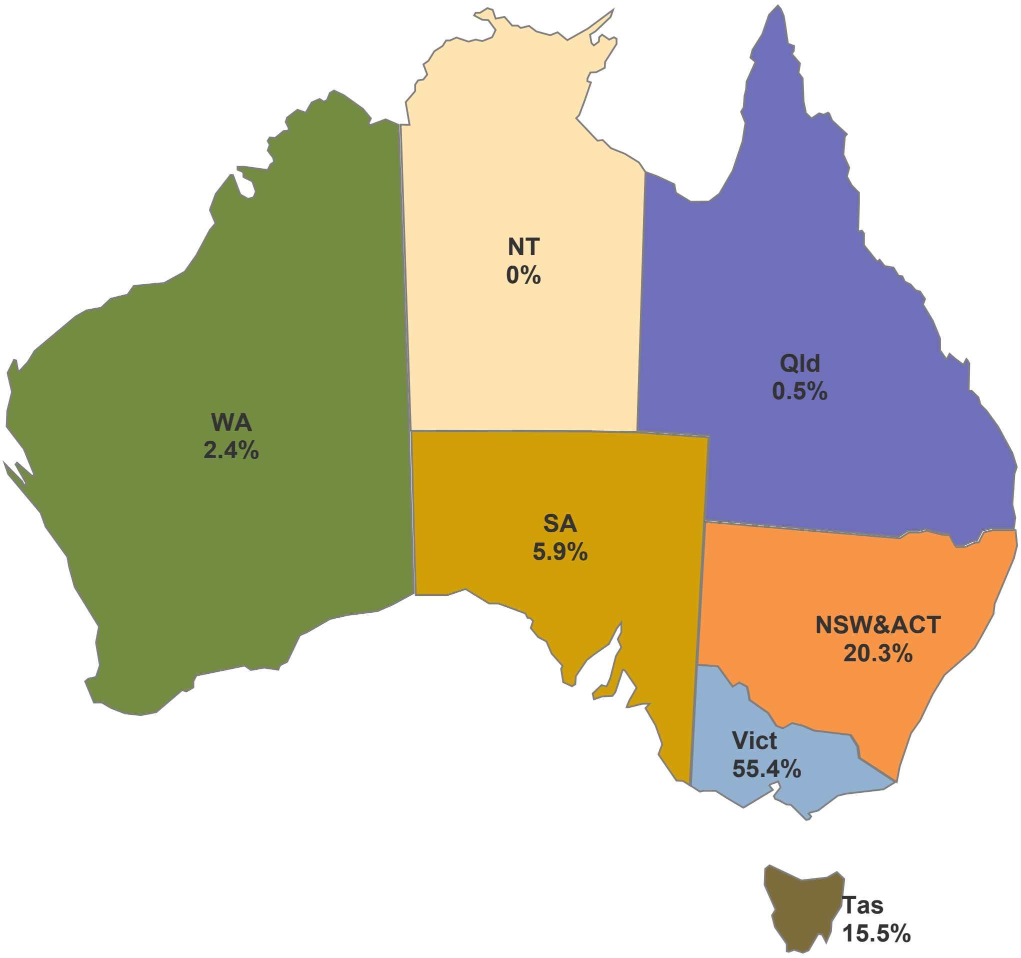


Figure 7 House Loss from Bushfires 1939-2006 based on Blanchi 2007[33]

4.2.6. Average Housing Losses attributable to Bushfires based on distance from adjacent bushland

Loss data for buildings other than single dwellings is limited and therefore analysis of single dwellings will be undertaken to provide an indication of how buildings of other classes, but of similar construction, would behave. Chen and McAneney[34] estimated that on average 105 house equivalents were lost to Bushfires / annum in Australia from 1900 to 2009. Blanchi[35] estimated that there were approximately 156 house losses / annum from 1939-2009, 171 from 1959-2009 and 318 from 1999-2009. The 1999-2009 average of 318 was dominated by the 2009 fires where over 2000 houses were lost and is therefore not representative of the long-term average. For the purposes of this analysis the average over the 70-year period of 156 was used to avoid shorter term fluctuations from single events noting that it may be an over estimate compared to the normalized value from Chen and McAneney.

Chen and McAneney also analysed building losses based on the distance from adjacent bushland after major fires. Their findings are shown in Figure 8 which plots the percentile of all destroyed buildings against distance from adjacent bushland with and without the Duffy fires. The Duffy fires differed substantially from other major bushfires with building losses extending further into the built environment. It should be noted that the predominant vegetation was a pine plantation which generated severe ember attack.

Based on these distributions it can be observed that typically 40% of house losses occur within 10m of the "bushland", 60% within 30m, over 70% within 50m and 85% within 100m and approximately 99% within 300m

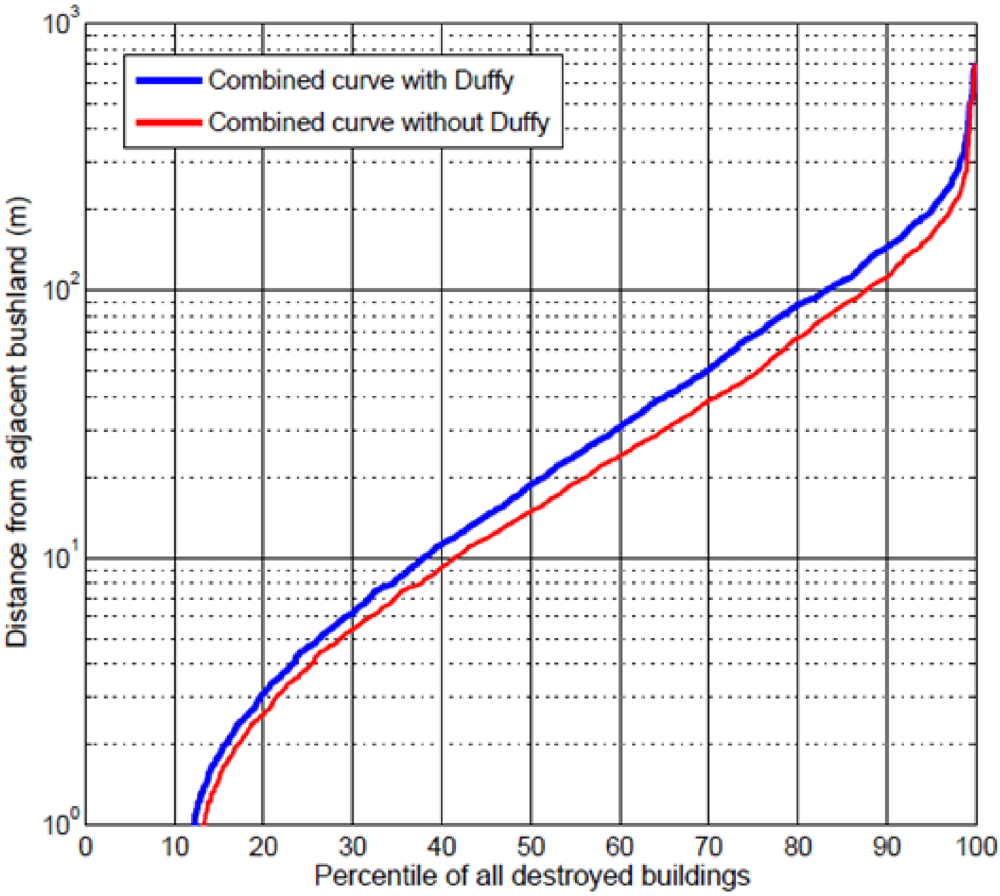


Figure 8 Cumulative distribution of house loses relative to distance from bushland (courtesy Risk Frontiers)

Chen and McAneney also referred to earlier work by Risk Frontiers indicating there are approximately 550,000 addresses within 100 m of larger and continuous bushland with an area threshold of 0.5 km^2 in Australia. Risk Frontiers provided updated values as detailed below for a previous ABCB project[36] (excluding Northern Territories were bushfire losses tend to be low despite a high frequency of bushfires):

Addresses within 100m of bushland; 626,000

Addresses within 30m of bushland; 360,000

Table 6 summarises the above findings with respect to the % of house losses and fatalities occurring as the distance from the forest increases.

Table 6 Cumulative Bushfire losses relative to interface with Bushland or forest

Distance from Bushland or forest	Estimated number of houses at risk	Cumulative % house loss	Cumulative % of fatalities that occurred within houses
10 m		40	76
30 m	360,000	60	88
50 m		70	95
100 m	626,000	85	100

Total number of residences in and around major cities has been assumed to be approximately 8,161,680 from Chen[37]. This is understood to exclude Northern Territories where bushfire losses are low despite there being high numbers of fires.

Parameter	0-30m from vegetation	0-100m from vegetation	30m-100m from vegetation
House loss %	60	85	25
Number of houses lost / annum	94	133	39
Number of houses within distance	360,000	626,000	266,000
Probability of house loss/annum x 10^{-4}	2.6	2.1	1.5

Notes Average house loss per annum 156

4.2.7. House losses and FFDI

For the period 1939 – 2006, Blanchi [33] estimated that 90% of house loss occurred above an FFDI of 55 and 70% above an FFDI of 100 which is consistent with major losses / life and property occurring from a limited number of events with severe fire conditions as identified in Table 5.

4.2.8. Hazards Associated with Evacuations

4.2.8.1. General Evacuation Hazards

The safest option is to evacuate early, before bushfires threaten the area at risk. Since bushfires can be unpredictable and can spread rapidly once ignited, in effect this means that the safest option is to evacuate the day before or very early on days of high risk.

Once bushfires approach an area there is a high risk associated with evacuation since the protection provided by a vehicle is limited and people exposed without protection are more vulnerable. This is demonstrated from the fatalities listed in Table 3 for the period 1965-2011 where 12% of fatalities occurred within vehicles and 42% in the open air.

The activities of the person immediately prior to their death were analysed by Blanchi:

For the period from 1901 to 2011 late evacuation was the most common activity (30.4%), followed by sheltering inside a structure (24.8%) and defending a property outside (22.4%).

For the period 1965-2011 sheltering inside a structure (40.2%) was the most common activity but late evacuation (24.8%) and defending property outside (16.3%) were still significant proportions.

4.2.8.2. Increased risks for vulnerable occupants

The increased risk was demonstrated during the Black Saturday fires where two aged-care facilities in the Bunyip area were evacuated. The evacuations were not undertaken prior to bushfires approaching the surrounding area and appropriate vehicles were not available for all the occupants. There were 82 occupied beds in the facilities at the time of the fire most of which could be considered to be highly vulnerable, four of which died in the ensuing days and it was stated in evidence to the Royal Commission[26] that the deaths could be attributed to the disruption and shock of evacuation. This represents approximately 5% of those evacuated.

The number of fatalities may have been reduced with earlier evacuation using ambulances or similar specialised transport for those most at risk

4.2.8.3. Frequency and timing of Evacuations

Advice issued to residents in bushfire prone areas as part of the Fire Danger Rating System [5] generally indicates the following:

Code Red (FDI 100+) Leaving is the best option

Extreme (FDI 75-99) Leaving is the safest option for your survival

Severe (FDI 50-74) Leaving is the safest option for your survival. Your home will only offer safety if it and you are well prepared and you can actively defend it during a fire.

Very High (FDI 25-49) Leaving is the safest option for your survival. Your home will only offer safety if it is and you are well prepared and can actively defend it during a bushfire.

However, the implementations vary slightly between jurisdictions with recommendations for evacuation focussing on severe and above conditions.

The review of fatalities and house losses presented in previous sections indicated 5 or more fatalities and over 90% of housing losses from fire events with FFDIs of 55 or greater and 11 or more fatalities and 70% of housing losses with FFDIs greater than 75. It is therefore considered reasonable to consider evacuation thresholds at the severe and extreme fire danger ratings (FFDIs of 50 and 75 respectively) in most instances.

In order to determine the likely need and frequencies of evacuations and potential variability between locations, data from Dowdy [38] was examined which included weather data from six locations which were chosen partly because they represented a reasonably broad range of different climate types and also because significant fire events (e.g. crowning and breaking of containment lines) occurred at each of these locations during the period of available data (Jan 2000 to December 2007). House losses were reported for the Warragamba, Canberra, Wangary and Scamander fires and life loss occurred as a result of the Canberra, Wangary, Scamander fires.

Daily FFDI values plotted against FWI (an alternate fire danger index) for the eight-year period are plotted in Figure 9.

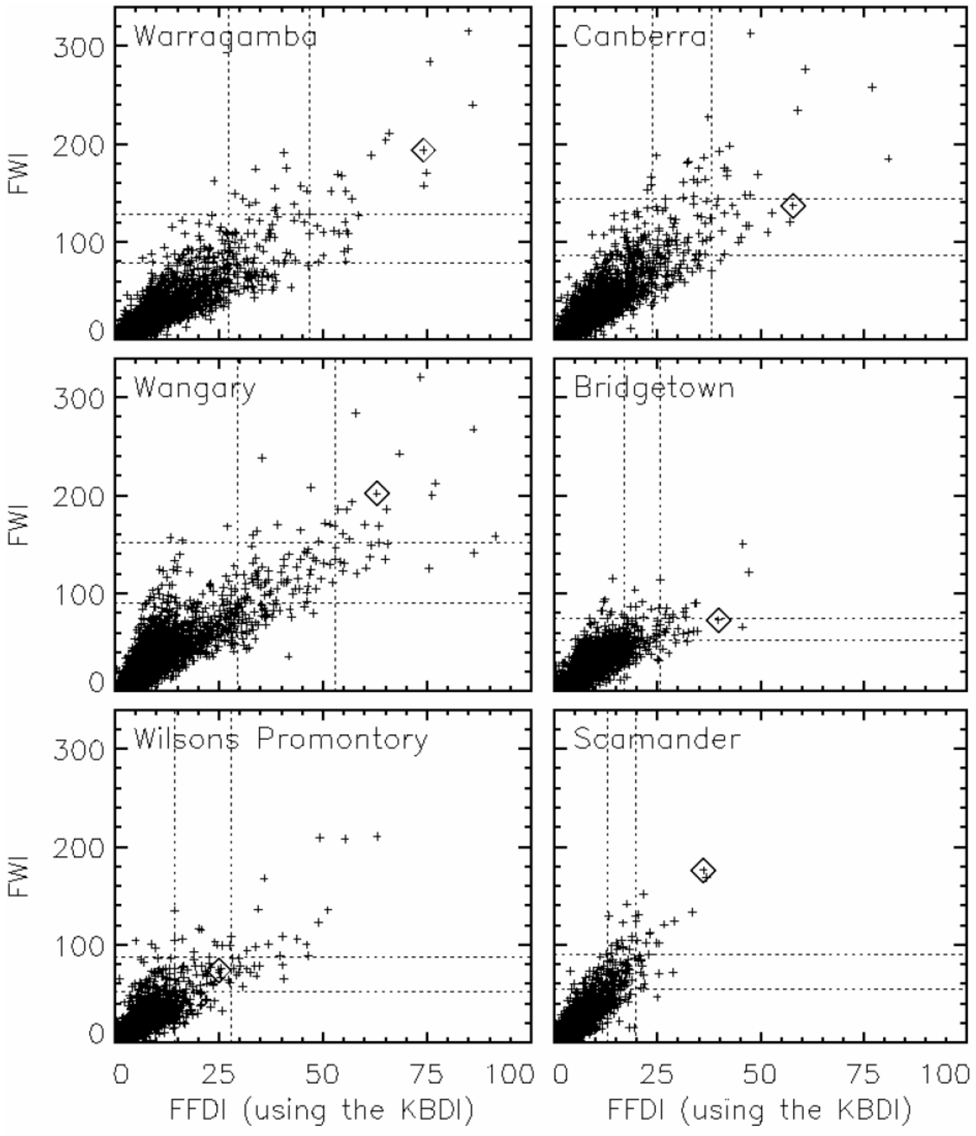


Figure 9 Daily values of the FWI versus the FFDI (based on the KBDI), for six sites from Dowdy [38]

Note 1 The 99th and 95th percentiles of the indices are shown as dashed lines.
Note 2 The day of a significant fire event is highlighted by a '◊' at each location.

The average number of days / annum, the FFDI thresholds of 50 and 75 were exceeded are summarised in Table 7

Table 7 Days FFDI thresholds were exceeded between Jan 2000 and December 2007

Local Area	State	Number of Days with FFDI > 50 / annum	Number of Days with FFDI >75 / annuum	Approx. FFDI on fire day	Fatalities from fire
Warragamba	NSW	3	0.75	75	0
Canberra	ACT	1	0.25	57	4
Wangary	SA	4.375	0.75	63	9
Bridgetown	WA	0	0	40	0
Wilsons Prom.	VIC	0.375	0	25	0
Scamander	TAS	0	0	37	1

Dowdy[38] observed that; “the Australia-wide threshold for a fire weather warning to be issued was originally set at a value of the FFDI equal to 50. In Tasmania, this threshold has been lowered to 24 because significant fire activity was happening at these levels. To support the use of this lower threshold, two further arguments were used. First, the warning is a public message and if the level were set at 50, the warning would be issued too infrequently to be effective. Second, implicit in the FFDI is an assumption of a standard fuel load which is significantly exceeded in the densely forested parts of Tasmania”

Whilst this predates the review of the Fire danger Rating System after the Black Saturday fires in 2009 it may explain the inclusion of leaving is the safest options at the very high range (25-50). An FFDI threshold of 25 was exceeded on average approximately 0.75 days / annum based on the Scamander data.

Based on the above analysis if an early evacuation strategy rather than defend in place were to be adopted for Class 9 buildings housing vulnerable occupants a reasonable evacuation threshold could be of the order of FFDI 50 although for some jurisdictions a lower threshold of 25 may be considered appropriate (e.g. Tasmania).

If these values are adopted the number of evacuations required per annum based on the above data would be in the range of 1-5.

4.3. Role of Class 9 buildings During Bushfire Events.

Total evacuation of hospitals and, as noted in section 4.2.8.2, evacuation of high dependency occupants of residential aged care facilities cannot be undertaken without exposing some occupants to significant risks due to the disruption to the care, increased stress and potential exposure to high temperatures and smoke during the relocation process. Whilst early evacuation of some occupants of these buildings could be achieved safely there will, in many instances, be a need for a defend in place strategy for the more vulnerable occupants.

Therefore, some class 9a and Class 9c buildings will need to maintain a tenable environment within the structure during and after exposure to bushfire and maintain essential services such as air conditioning, medical gas supplies etc.

For schools and early childhood centres evacuation is more practical unless it is a residential facility since the school can be simply closed on high risk days. This approach is applied on Code Red days in Victoria [39] although consideration could be given to extending this to FFDIs below 100 as an alternative to providing highly protected buildings. However, this should be balanced against sending children home to residences that may be more vulnerable to bushfire attack.

4.4. Building Characterisation and Mitigation Measures for Evaluation

4.4.1. Form of Construction and General Layout

In order to undertake the Risk Assessment, it is necessary to characterise generic class 9 buildings. The least fire-resistant construction is Type C which applies to single storey Class 9 buildings which may be of similar construction to single dwellings (e.g. light weight construction or brick veneer). These types of building are relatively common close to the urban interface and therefore have been selected for the comparison.

Generic layouts are shown in Figure 10 through Figure 12 for Class 9c, 9a and 9b respectively based on NCC DtS requirements excluding Part G. No FRLS are applicable to the general structure or external walls with the only formal compartmentation being smoke separation of the ward areas and ancillary areas in 9c buildings and fire separation (FRL 60/60/60) of ward and ancillary areas in Class 9a buildings. The external walls can be combustible in Type C construction.

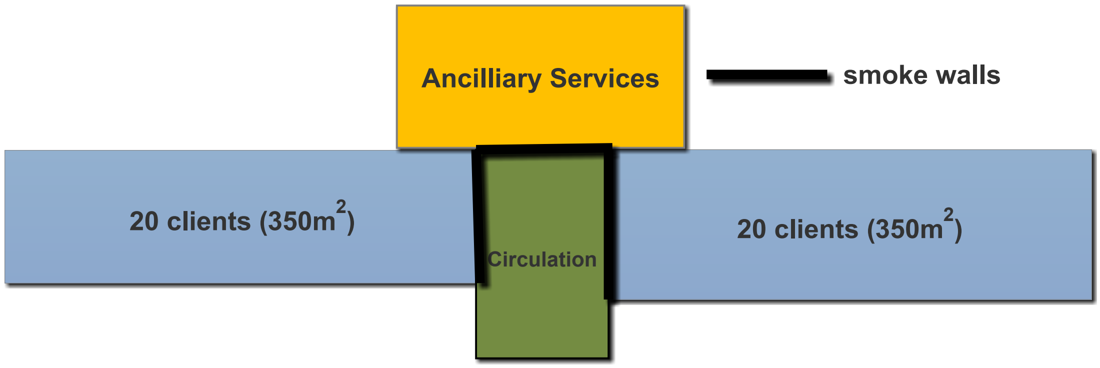


Figure 10 Schematic Layout of Class 9c single storey building

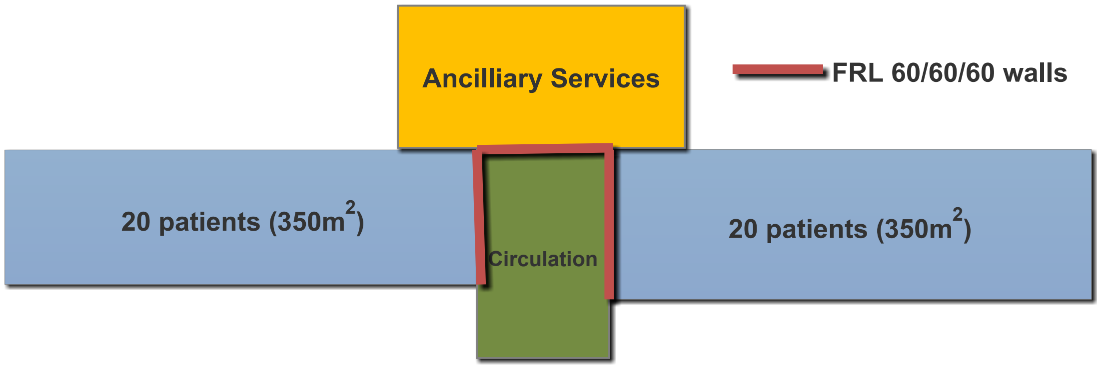


Figure 11 Schematic Layout of Class 9a single storey building

Figure 12 Schematic Layout of Class 9b single storey building

4.4.2. Mitigation Measure Options

Three potential mitigation measure options have been identified for initial consideration and are listed in order of stringency (and cost):

- Basic compliance with the NCC DtS requirements excluding Part G provisions relating to Bushfire protection
- Compliance with the NCC provisions including Part G
- Enhanced protection based on requirements for Community Bushfire Refuges as defined in the ABCB non-mandatory - Handbook[18]. It should be noted that some requirements for Community Bushfire Refuges may not be appropriate for buildings housing vulnerable occupants (e.g. max permitted internal temperatures) and may require some adjustment.

The mitigation options are summarised and compared in Table 8.

Table 8 Comparison of Initial Mitigation Measure Options

Parameter	Current NCC provisions Design Consideration	Current NCC provisions plus Part G Bushfire Protection	Enhanced Provisions - Community Bushfire Refuge requirements
Separation from primary vegetation	Not required	Varies between 0 and 100m with protection levels determined based on AS 3959 site assessment. No separation BAL FZ construction	Radiant heat flux exposure not exceeding 10kW/m^2 or; FRL of 60/60/60 and any openings protected to maintain FRL
Separation between buildings	6m or more no protection Less than 6m at least 60/60/60	6m or more no protection Less than 6m at least 60/60/60 plus protection against bushfire attack	10m minimum or; FRL of 60/60/60 and any openings suitably protected or; radiant heat flux not exceeding 10kW/m^2
Separation distance from allotment boundaries	3m or more no protection Less than 3m at least 60/60/60	3m or more no protection Less than 3m at least 60/60/60 plus protection against bushfire attack	10 m minimum, or; FRL of 60/60/60 and with any openings suitably protected, or; radiant heat flux not exceeding 10kW/m^2.
Separation distance from car parking areas	No requirement	No requirement	10 m minimum, or; FRL of 60/60/60 and with any openings suitably protected, or; radiant heat flux not exceeding 10kW/m^2.
Separation distance to other hazards e.g. gas bottles / medical gas storage etc.	No requirement	No requirement	heat flux not exceeding 10kW/m^2 from all sources
Provision of non-combustible paths around building	No requirement	No requirement	1.5m wide around the perimeter of the refuge.

Parameter	Current NCC provisions Design Consideration	Current NCC provisions plus Part G Bushfire Protection	Enhanced Provisions - Community Bushfire Refuge requirements
Max permitted radiant heat flux from bushfire on exposed building elements	No requirement	Can vary based on BAL assessment from 12kW/m^2 to flame immersion (construction varies with exposure)	Maximum 10kW/m^2
Special access provisions to buildings	Basic NCC access and egress provisions	Basic NCC access and egress provisions	Main access doorways to be automatic opening if building is operating as a refuge and access pathways should be readily identifiable and have a relatively even surface access pathways should have a minimum clear width of 1m
External areas where occupants may be exposed to radiant heat flux from fire front	No requirements	No requirements	Maximum radiant heat flux of 1 kW/m^2. (assumed to exclude contribution from the sun)
Internal tenability	No requirement	No requirements.	Duration of occupancy Max air temp limit 45°C Mean air temp limit 39°C (lower values may be applicable to vulnerable occupants) Maximum internal surface temp 60°C Toxicity limits are also applied to building materials Natural ventilation must be provided by openings such as doors or other devices that, when open, have an aggregate open area of not less than 5% of the floor area of the refuge; or a mechanical air-handling system must be provided to maintain adequate air quality.

Parameter	Current NCC provisions Design Consideration	Current NCC provisions plus Part G Bushfire Protection	Enhanced Provisions - Community Bushfire Refuge requirements
External Envelope	Generally, FRL required and combustible construction permitted if 3m separation from boundary and 6m from adjacent buildings maintained	External envelope designed to resist BAL exposure derived from AS 3959 site assessment	Requirement to maintain tenability infers external envelop will be resistant to bushfire attack including ember attack but specific details are not provided. Issues such as resistance to wind loads and collapsing trees identified as needing to be addressed as part of the structural design
Automatic internal sprinkler protection	Required for Class 9c buildings	Required for Class 9c buildings	Required for Class 9c buildings
External manual firefighting provisions	No specific requirements for bushfires	No specific requirements for bushfires	Coverage of the perimeter of the refuge for a distance of 10m perpendicular to the perimeter. A non-combustible water tank connected to a pump with sufficient back-up power to supply water to hose reels. Water tank capacity to be determined by the appropriate authority
Emergency Power Supply	No requirements	No requirements	Diesel powered generator and associated fuel storage to be provided Generator capacity to be determined by the appropriate authority. Diesel fuel storage capacity and location to be determined by the appropriate authority.
Maintenance of fire safety and other essential design components	Mandatory maintenance provisions differ between States and Territories and are outside the scope of the NCC	Mandatory maintenance provisions differ between States and Territories and are outside the scope of the NCC	Mandatory maintenance provisions differ between States and Territories and are outside the scope of the NCC

5. Scenario Development and Preliminary Qualitative Risk Assessment

5.1. Fire Safety Concepts Tree Analysis

5.1.1. Overview of the Fire Safety Concepts Tree

The NFPA fire safety concepts tree [3] has been adopted to provide structure for the scenario development and Preliminary Qualitative Risk Assessment. The upper branches of the concepts tree are shown in Figure 13. Below is a key for the concepts tree OR and AND gates

= OR indicates any of the concepts below the gate will cause or have as an outcome the concept above it

= AND indicates all of the concepts below the gate are needed to achieve the outcome of the concept above it

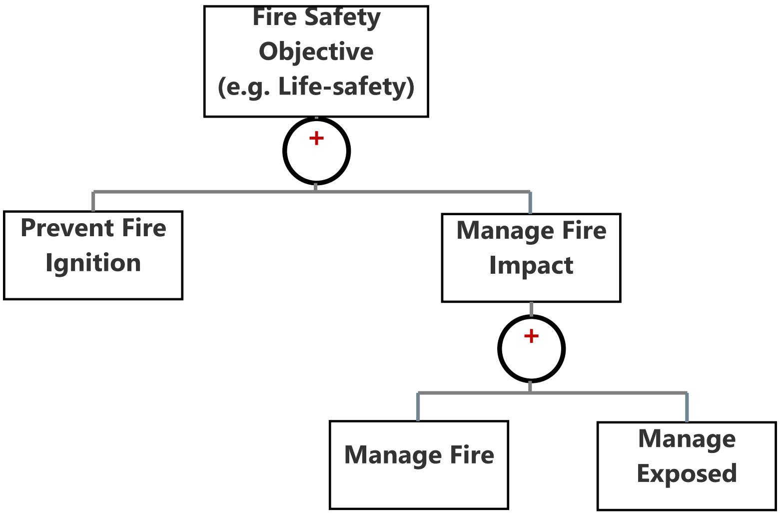


Figure 13 Upper Branches of Fire Safety Concepts tree

In this instance the Fire Safety Objective is the life safety of the vulnerable occupants in Class 9 buildings.

In the following discussion branch descriptions have been italicised for clarity:

Consideration of actions to *Prevent Fire Ignition* of a bushfire such that there is no bushfire event to threaten the Class 9 building or to *Manage Fire* such that the allotment on which a Class 9 building is constructed is not exposed to Bushfire Attack lie outside the scope of this study because the building construction will have no influence on the likelihood of the bushfire attack occurring. Prevention and general management of bushfire are impacted by planning and emergency management processes, amongst other things.

The frequency of bushfire attack at a specific location (allotment) is expected to be the same irrespective of the Class and Building unless the vegetation management in the surrounding area is different Therefore when considering a specific location the frequency of bushfire attack for a class 9b building will be similar to that estimated for a residential building.

This will enable predictions to be made based on loss statistics.

The detailed analysis will therefore assume that the bushfire has occurred and has spread to "Classified Vegetation" close to a class 9 building; leaving manage the fire or manage the vulnerable occupants exposed to the bushfire risk as mitigation options for further evaluation.

Note: Due to the greater numbers of single dwellings within Bushfire Prone areas compared to Class 1a single dwellings

5.1.2. Manage Fire Branch

The *manage fire* branch is expanded in Figure 14.

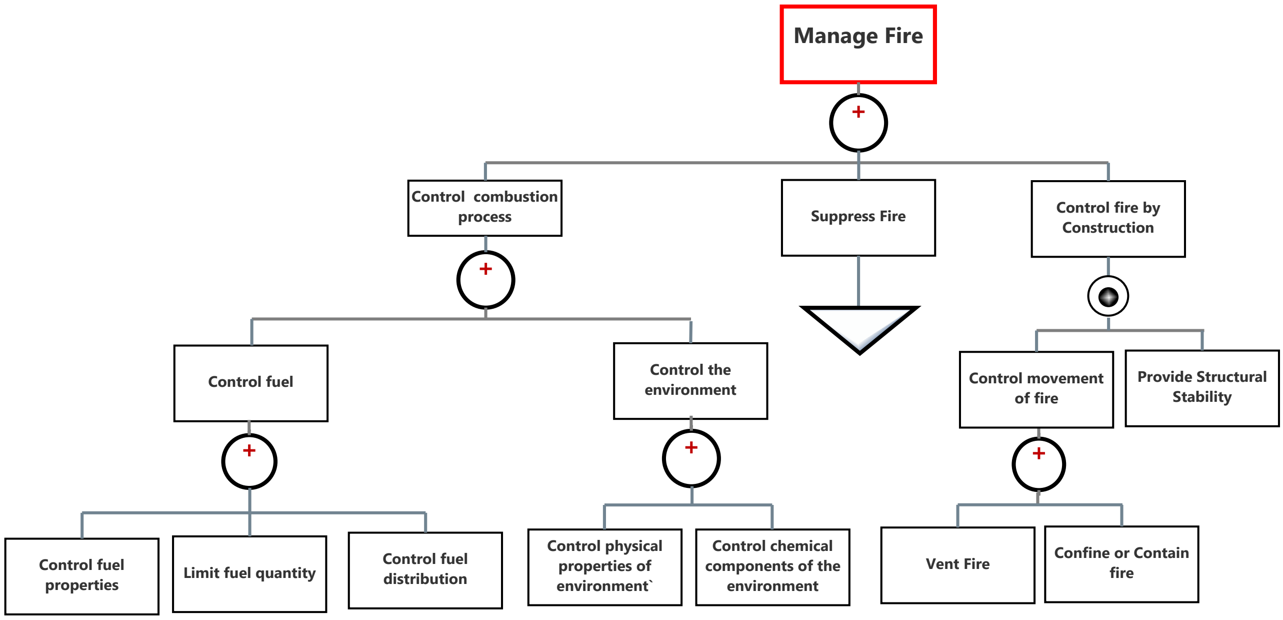


Figure 14 Expanded Manage Fire Branch

5.1.2.1. Control Combustion Process

To control the combustion process there are two options

- *Control fuel* or
- *Control the environment*

The control fuel option has an or gate with the following three options

Control fuel properties: This can be achieved by for example selection of low risk vegetation close to the building and ongoing vegetation management, application of fire retardants to combustible materials and / or selection of materials with limited combustibility that are external to the building but may become involved such as garden furniture, fences and the like.

Limit fuel quantity: This can be achieved by, for example, limiting vegetation and other combustible such as; external furnishing and structures, gas and / or medical gases adjacent to the subject building for example

Control fuel distribution: Where fuels cannot be limited, locate the potential fuels away from the building. This could include removal of external furniture and other items at times when the risk of bushfire attack is high and specification of separation distances.

Control the environment outside a building has limited application. To some extent the use of an external sprinkler system / drencher system could be considered to have an influence of the physical properties of the environment adjacent to the structure, but the impact of sprinkler protection is addressed under the supress fire branch of the concepts tree which is discussed in Section 5.1.2.3

Based on the above discussion;

Basic compliance with the NCC DtS requirements excluding Part G provisions relating to Bushfire protection would have a minimal impact on the control of the combustion process external to a Class 9 building

The NCC provisions including Part G and the Enhanced requirements include a number of measures that contribute to the control of the combustion process external to a Class 9 building with the enhanced requirements being more stringent

5.1.2.2. Control Fire by Construction

The *control fire by construction* concept can be achieved by the combination of *providing structural adequacy* and the *control of the movement of the fire* by adopting a design for the external building envelope that is resistant to the various bushfire attack mechanisms applicable to the building (e.g. embers, radiant heat, flame contact and impact resistance).

Basic compliance with the NCC DtS requirements excluding Part G provisions relating to Bushfire protection would have a minimal impact on the *control of fire by construction* concept. For example, window openings and the lack of requirements for ember protection could leave the building vulnerable to bushfire attack

The NCC provisions including Part G and the Enhanced requirements include a number of measures that contribute to the *control of fire by construction* concept, with the enhanced requirements being more stringent

5.1.2.3. Suppress Fire

The expanded *suppress fire* branch is shown in Figure 15.

External sprinkler protection can:

- reduce the probability for external ignition and subsequent fire spread of combustible materials forming part of the external façade of the building.
- suppress flaming embers / debris that may collect against the building facade
- pre-wet combustible materials reducing the probability of ignition
- provide additional protection to windows and doors

The effectiveness of external sprinklers is expected to be substantially less than internal sprinkler systems suppressing typical building fires due, amongst other things, to the influence of wind, difficulty optimising activation times during fires, variability of location and fire size. This is acknowledged in AS 5414-2012 Bushfire water spray systems[40] which sets out general requirements for the design, installation and maintenance of water spray systems intended to provide a degree of building protection against bushfire exposure. The scope of the standard limits the applicability to ember attack, together with limited protection against radiant heat exposure up to 19 kW/m^2 (AS 3959 - BAL 19) and indicates that bushfire water spray systems are intended to complement the requirements of AS 3959.

External sprinkler or water sprays are not generally required for any of the three protection options being considered.

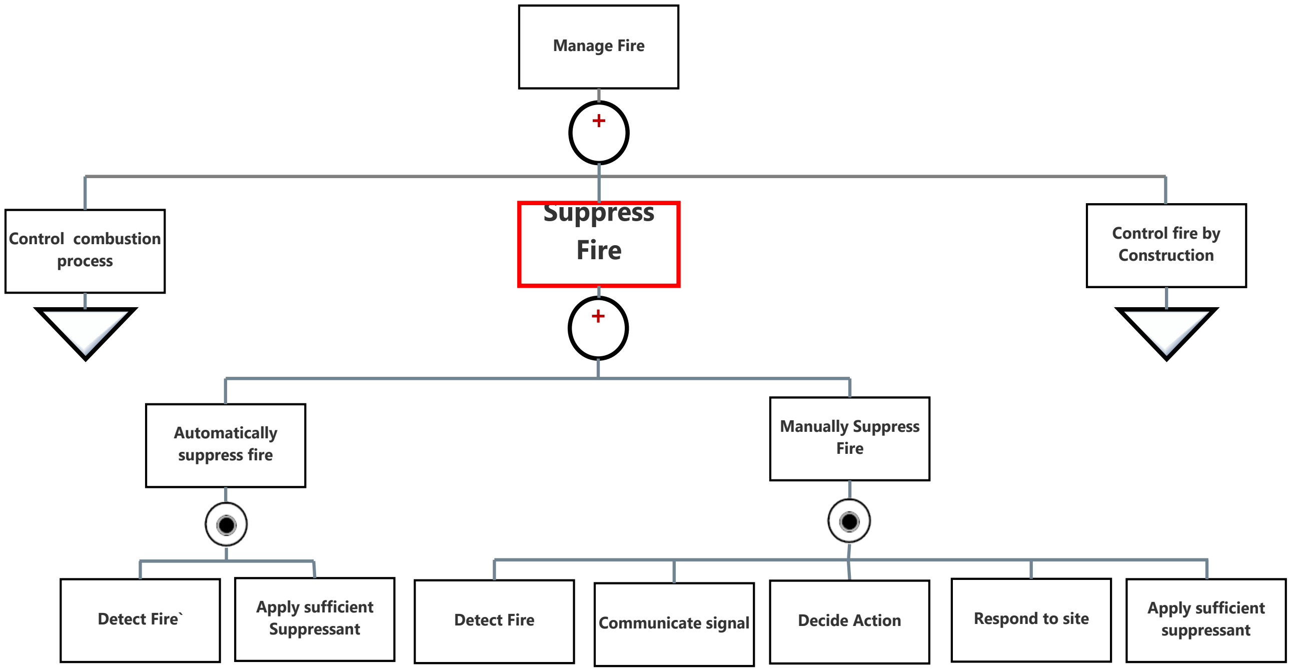


Figure 15 Expanded Suppress Fire Branch

Internal sprinkler protection could have an impact on fire propagation within a building if the building envelope is breached but the effectiveness would be expected to be less that the response to a normal building fires because of the potential for multiple fire starts if there are multiple breaches, greater probability of cavity fires that may be shielded from the sprinklers and potential for sprinkler control equipment to be exposed to fire.

Sprinkler protection will therefore be assumed as a secondary system if provided.

For Class 9c buildings and Class 9a buildings used as residential aged care building the NCC[6] requires internal sprinkler protection which therefore applies to all three options under consideration. Class 9b buildings used as schools or early learning centres would not require internal sprinkler protection for all three of the proposed options.

The *manually suppress fire* concept is achieved by an and gate requiring all of the following to be achieved;

- *Detect Fire*
- *Communicate Signal*
- *Decide Action*
- *Respond to Site*
- *Apply sufficient suppressant*

In the case of Bushfire attack there will be high probabilities that the fire will be detected, and the risk communicated even without automatic suppression systems. However, in Class 9 buildings housing vulnerable occupants' staff would be expected to be attending occupants and their availability to undertake external fire suppression activities would be limited and therefore reliance would tend to be placed on emergency services or other volunteers to undertake manual suppression activities. Therefore, the need for assistance would need to be communicated and resources would need to respond to the site in many instances lowering the probability of successful manual suppression.

For successful suppression a means of delivering the suppressant (e.g. hoses) and sufficient suppressant should be available – generally by means of water tanks and pumps.

Manual suppression activities have been shown to significantly improve house survival. For example, Ramsay [41] analysed fire losses from the Otway Ranges after the Ash Wednesday fires and determined the risks in Table 9 relative to a reference value of 1 assigned to unoccupied dwellings.

Table 9 Otway Ranges Survey – Effect of Occupant Action from Ramsay [41]

Action	Relative Risk[1]
Stayed	0.1
Left-returned after 30 minutes	0.4
Left -stayed away	0.6
Unoccupied	1.0

Note 1 Unoccupied assigned a reference value of 1.0

The BCRC Final report to the Royal Commission[42] provided data on the impact of the defense of using water which is summarized in Table 10 and clearly shows a significant reduction in losses if a building is defended with water.

Table 10 Extent of damage based on building defence with water extracted from BCRC Final Report to the Royal Commission[42]

House damage	Evidence of water used (sample size 248)	No evidence of water use (sample size 495)
Untouched	33%	12%
Damaged	34%	10%
Destroyed	33%	78%

There are no specific manual firefighting provisions for the basic compliance option with the NCC excluding Part G requirements relating to Bushfire protection or the option including the Part G requirements. However basic building fire hydrant provisions would apply, and some State and Territory regulations or NCC modifications contain additional requirements for manual firefighting provisions. The Enhanced requirements include specific requirements for manual firefighting coverage and water supplies.

If firefighters can respond to the building the provision of enhanced water supplies and coverage around the building would be expected to significantly increase the probability of survival based on the data presented in Table 10.

5.1.3. Manage Exposed

The *manage exposed* part of the concepts tree (refer Figure 13) is expanded in Figure 16. In the context of Bushfire Exposure the *limit amount exposed* branch can be addressed by requiring Class 9 buildings housing vulnerable occupants to be sited outside areas that have a significant bushfire threat. This option is addressed by means of the planning process but total prohibition is not a practical solution particularly where there are existing communities. Since the focus of this report is to consider building solutions to mitigate the bushfire risk, the remainder of this qualitative review will focus on the safeguard the exposed branch option. Safeguarding the exposed can be achieve by either defending in place or moving the exposed.

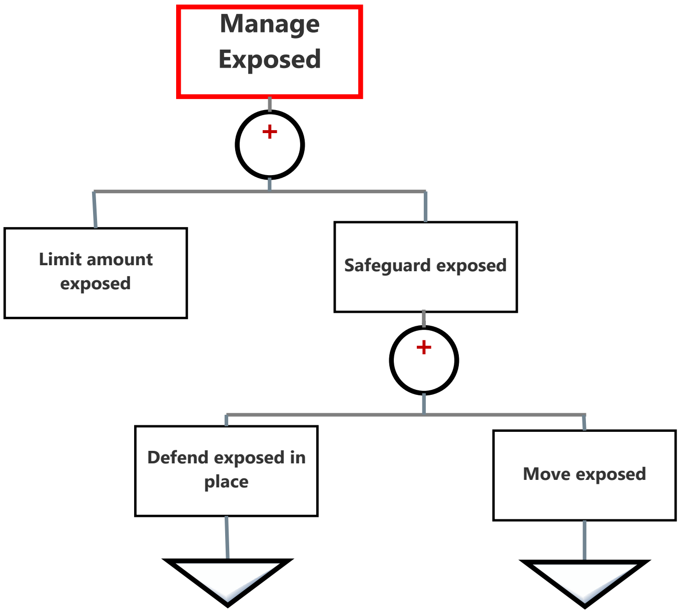


Figure 16 Manage Exposed Branch of the Fire Safety Concepts Tree

5.1.3.1. Defend Exposed in Place

The expanded *defend exposed in place* branch is shown in Figure 17

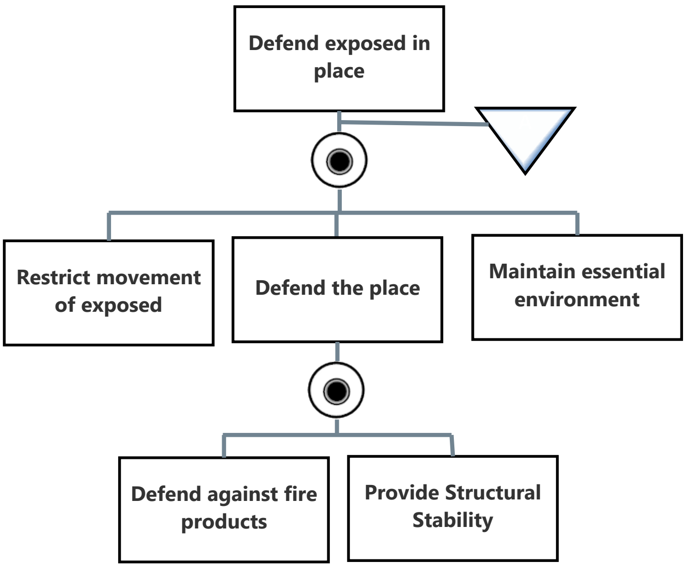


Figure 17 Expanded defend exposed in place branch

In order to *defend the exposed in place* it is necessary to *restrict movement of exposed, defend the place and maintain the essential environment*. All these three concepts need to be achieved to successfully defend the exposed in place.

Restrict Movement of Exposed: For Class 9 buildings housing vulnerable occupants, unless the building is a secure facility, reliance is placed on the staff to ensure mobile occupants stay within the defended place. This may require special attention for occupants that may not perceive a significant risk such as the very young in schools and elderly people with dementia for example. With respect to the young, training programs within schools may provide a better understanding of the risks associated with fire.

Defend the Place: The defend the place concept can be achieved by *defending against fire products* and *providing Structural Stability*. Basic compliance with the NCC DtS requirements excluding Part G provisions relating to Bushfire protection would have a minimal impact on the control of fire by construction concept. For example, window openings and the lack of requirements for ember protection could leave the building vulnerable to bushfire attack. The NCC provisions including Part G and the Enhanced requirements include a number of measures that contribute to defending the place, with the enhanced requirements being more stringent.

Maintain Essential Environment: If a building successfully resists bushfire attack (*defends the place*) occupants could still be placed at risk if the essential environment within the building is not maintained. This is more critical for buildings housing vulnerable occupants that may be more susceptible to heat stress and smoke exposure. Basic compliance with the NCC DtS requirements (with or without the Part G provisions relating to Bushfire protection) may provide a limited contribution to *maintaining the essential environment* if the building envelop remains intact. However, the essential environment during a bushfire is not explicitly addressed nor are issues such as smoke infiltration, development of excessive temperatures in the event of air conditioning failure and maintenance of operational status of other essential equipment such as medical equipment and communication systems. This is consistent with the NCC approach to housing where the building can provide short term protection during the passage of the fire front, but tenable internal conditions are not required to be maintained. The Enhanced requirements include a number of measures that contribute to maintaining the essential environment within the building.

5.1.3.2. Move Exposed

The *move exposed* branch is shown in Figure 18;

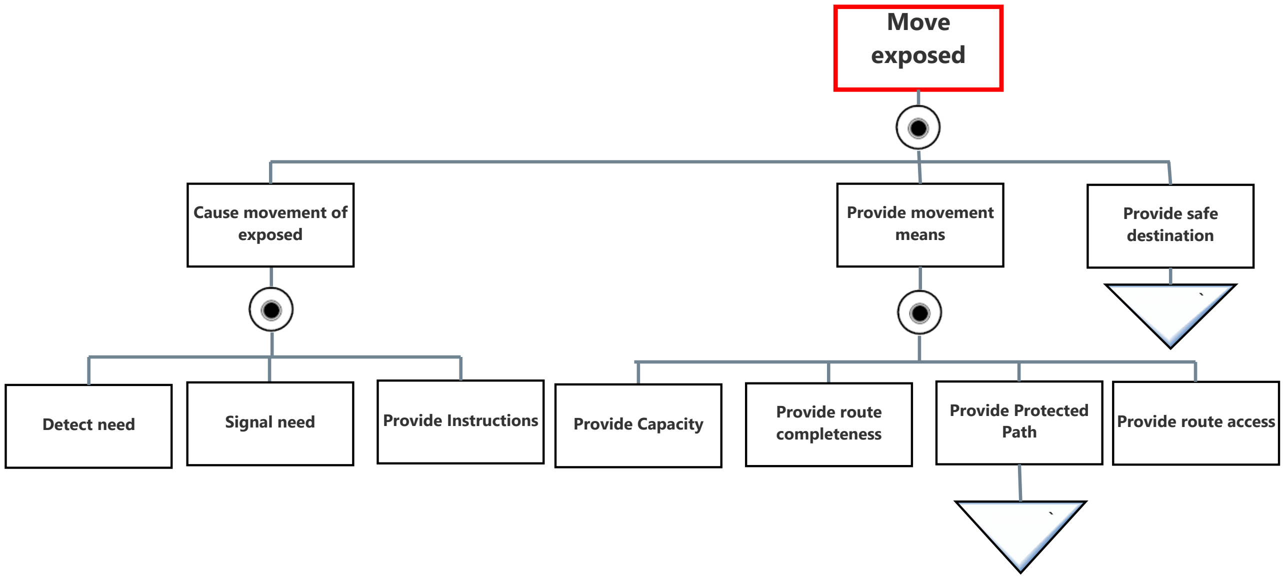


Figure 18 Expanded Move Exposed Branch

The *move exposed* gate requires all the following concepts to be successfully achieved:

- *Cause movement of exposed, and*
- *Provide Movement Means, and*

* *Provide a Safe Destination*

Cause Movement of Exposed

In order to cause movement, all the following have to be achieved:

* *Detect the need*
* *Signal the need*
* *Provide Instructions*

There is a national warning system in place for Bushfires[5] and various initiatives to advise operators of Class 9 facilities of appropriate actions to consider in a fire emergency. Typical examples are;

Residential aged care services bushfire ready resource[21].

Relocation, shelter in place and evacuation - Guidance note for public and private health services, hospitals and residential aged care services[43].

These and other guides focus on early evacuation typically the day before or early morning triggered by thresholds in the national warning system based on fire weather conditions amongst other things if an evacuation strategy is selected.

Whilst the above concepts are not directly related to the construction of buildings in bushfire prone areas the likely efficacy and decisions made need to be considered when determining whether a building may be occupied when exposed to bushfire attack. Refer Section 4.2.8.3 for further background information

Provide Movement Means

In order to *provide movement means* the fire safety concept requires all of the following to be achieved;

* *Provide Capacity*
* *Provide Route Completeness*
* *Provide Protected Path*
* *Provide Route access*

***Provide Capacity*:**

In the context of evacuation from a Bushfire hazard, provide capacity is interpreted as provision of appropriate vehicles to transport evacuees to a safe place. When considering the evacuation of vulnerable occupants, specialist transport such as ambulances may be required which may challenge available resources particularly if large areas are under threat. Refer Section 4.2.8 for further discussion.

***Provide Route Completeness*:**

To achieve this concept access must be provided for the type of vehicles required for the evacuation. Whilst provision of access is commonly addressed through planning regulations rather than building regulations it is noted that the Tasmanian Appendix to the NCC modifies performance requirement GP 5.1 to address evacuation as indicated below:

A building that is constructed in a designated bushfire prone area must, to the degree necessary, be—

(a) designed and constructed to reduce the risk of ignition from a bushfire, appropriate to the—

(i) potential for ignition caused by burning embers, radiant heat or flame generated by a bushfire; and

(ii) intensity of the bushfire attack on the building; and

(b) provided with vehicular access to the site to assist firefighting and emergency personnel defend the building or evacuate occupants; and

(c) provided with access at all times to a sufficient supply of water for firefighting purposes on the site.

Provide Protected Path **and** ***Provide Route Access*****:**

All the concepts listed under the defend occupants in place option are required to provide a protected path. It is impractical to address these concepts once the bushfire approaches an area because of the limited protection offered by vehicles and risks associated with falling trees, blocked roads and low visibility. Therefore, in most cases these concepts can only be addressed by means of early evacuation before bushfires approach the site and on days of fire risk above a pre-defined threshold. Refer Section 4.2.8 for further discussion. Two possible exceptions to this are:

- where a *safe destination* is provided close to the building under consideration (for example on the same allotment). Such an approach has been applied in Victoria to some existing schools as described by Marquez [39]
- where there are alternative paths for moving to a *safe destination* together with means of communication to confirm the completeness of an evacuation route.

Provide a Safe Destination**:**

All the concepts listed under the *defend occupants in place* concept are required to provide a *safe destination*. Therefore, in most cases if a site is evacuated the most practical option is relocation to an area not under threat from bushfires.

5.2. Scenario Development

5.2.1. Prohibit Construction in Bushfire Prone Areas

The *limit amount exposed* branch of the Fire Safety Concepts tree is a simple but effective option to apply by prohibiting construction of Class 9 buildings housing vulnerable occupants in bushfire prone areas. In some cases, this could be a valid and reasonable solution. However existing communities need to be served by schools and health-care facilities and locating these services at substantial distances away from communities may increase other risks such as transport risks and health risks due to delayed treatments in addition to disadvantaging the local communities.

Since a blanket prohibition is not considered a suitable option in all cases, the prohibit construction of Class 9 buildings option and associated scenarios will not be considered further since the scope of this project is consideration of the requirements for Class 9 buildings if they are constructed within a Bushfire Prone Area. Notwithstanding this it would be prudent to site Class 9 buildings housing vulnerable occupants as far as practicable from the bushfire threat in cases where they have to be sited within Bushfire Prone areas.

5.2.2. Evacuation / Relocation Options

As identified in previous sections for Class 9a and 9c health care buildings in many instances evacuation of some vulnerable occupants may not be practicable or safe and total evacuation strategies are therefore not viable for all Class 9a and Class 9c buildings.

A variant of total early evacuation / relocation options is potentially viable for non-residential Class 9b schools and early child-care centres where parents are notified of a school closure the day before weather conditions are predicted to exceed pre-defined bushfire warning thresholds. Parents can then implement their Bushfire plans having regard, amongst other things, to the bushfire threat to their dwelling. Marquez [39] describes an implementation of this approach in Victoria where schools are closed when Code Red days are predicted. The approach described by Marquez also allows varying protection levels for school buildings depending upon whether the building will be occupied during a bushfire emergency on days other than Code Red days.

Various Guides have been produced advising the person responsible for Class 9 buildings of their responsibilities to development emergency responses to Bushfire and these guides generally indicate that the person in charge (usually the CEO) has to decide on evacuation / relocation or defend in place strategies and implement them accordingly. Generally the advice takes a similar form to the Residential Aged Care Service Bushfire Ready Resource [21] which states amongst other things

"In considering the appropriate response to a potential or actual bushfire, a number of factors need to be considered:

- the nature of the threat — time, scope and proximity
- facility preparedness and location
- current resident/patient profile — acuity, care needs
- the likely impact of relocation on residents' health
- capacity to reduce resident numbers prior to the day
- availability of suitable and safe alternative accommodation
- availability of transport and road access
- safety to travel
- workforce and supplies availability
- support required from CFA/MFB to stay and remain on site."

It therefore follows that the response will vary between facilities even though the NCC Classification will be the same with some facilities having early evacuation strategies and some a defend in place strategy.

Generally, a level of redundancy should be provided in Emergency Plans particularly when addressing natural hazards such as Bushfires where the occurrence of a bushfire and fire behaviour are difficult to predict, and a building may be threatened at short notice on relatively low fire rating days. The NCC provisions therefore need to address evacuation / relocation and defend exposed in place options

5.2.3. Defend Exposed in Place

The defend exposed in place option scenario should be applied to all Class 9 buildings housing vulnerable occupants that would need to be used as a refuge if a defend in place strategy is adopted or in the event of failure of evacuation / relocation options.

Based on the Fire Safety Concepts Tree analysis the current NCC DtS provisions and performance requirements do not address matters such as the maintenance of an essential environment within a building and therefore the existing provisions were not considered viable options for further evaluation if a building is to provide a safe place for occupants during a bushfire event.

For larger sites it may be possible to consolidate the occupants into one or more "refuge buildings" on the site and apply less stringent levels of property protection typically consistent with the current NCC provisions applied to dwellings for buildings not occupied when exposed to bushfire attack, provided they are unlikely to initiate fire spread to a refuge building. This approach is consistent with the approach to schools described by Marquez[39]

5.3. Consolidation of Qualitative Risk Assessment and Options for Detailed Evaluation

5.3.1. General Conclusions

Based on the above preliminary analysis the following conclusions have been drawn

1. Evacuation / relocation of all occupants from some Class 9 buildings is impractical and if attempted may impact the health and safety of vulnerable occupants
2. There is a need to address a defend in place option for Class 9 buildings housing vulnerable occupants even if the preferred response is early evacuation / relocation
3. The current NCC performance requirements do not address the preservation of an essential environment within a building during a bushfire event and therefore will require modification to address the use of class 9 buildings as a refuge housing vulnerable occupants.
4. Performance requirements for provision of access to buildings for emergency services similar to the modification included in the NCC Tasmanian appendix should be included unless considered outside the NCC scope.
5. Performance requirements for external firefighting provisions including water supplies similar to the modification included in the NCC Tasmanian Appendix should be included.
6. An option should be provided to consolidate occupants into buildings suitable for use as a refuge and adopt a lower level of protection for non-critical buildings provided they do not expose the refuges to increased risks. The lower level of protection for other unoccupied buildings could be based on current NCC requirements applied to Class 2 and 3 buildings.

5.3.2. Options for Detailed Analysis

The following draft performance requirement is proposed for Class 9 buildings housing vulnerable occupants in Bushfire prone areas. It has been derived from the current NCC performance requirement GP5.1 as modified in the NCC by the Tasmanian appendix and the Design and Construction of Community Bushfire Refuges Handbook [18] with modifications to address permanent occupancy. The performance requirement also includes flexibility to use the Class 9 building housing vulnerable occupants to also provide shelter for other people:

GP5.2 Draft

A Class 9 building housing vulnerable occupants that may be used as a refuge for the vulnerable occupants (and other people) that is constructed in a designated bushfire prone area must, to the degree necessary, be—

(a) designed and constructed to reduce the risk of ignition from a bushfire, appropriate to the—
    (i) potential for ignition caused by burning embers, radiant heat or flame generated by a bushfire; and
    (ii) intensity of the bushfire attack on the building; and
(b) provided with vehicular access to the site to assist firefighting and emergency personnel defend the building or evacuate occupants; and

(c) provided with access at all times to a sufficient supply of water for firefighting purposes on the site.
(d) provide a tenable environment for occupants during the passage of untenable conditions arising from a bushfire event, appropriate to the –

i. location of the refuge relative to fire hazards including-
   aa) predominant vegetation; and
   bb) adjacent buildings, structures and movable objects; and
   cc) car parking area/s and allotment boundaries; and
   dd) other combustible materials;
ii. number of occupants to be accommodated within the refuge, and
iii. duration of occupancy, and
iv. bushfire intensity having regard to the bushfire attack level; and
v. intensity of potential consequential fires, and
vi. safe access within the site to the refuge, (including carpark areas), as well as occupant egress after the bushfire event; and
vii. occupant tenability within the refuge for the duration of occupancy before, during and after the bushfire event; and
viii. combined effects of structural, fire exposure and actions to which the refuge may reasonably be subjected; and
ix. provision of fire-fighting equipment and water supply to facilitate protection of the refuge

Table 11 gives proposed prescriptive design measures have been adapted from the Design and Construction of Community Bushfire Refuges Handbook criteria with modifications appropriate to an occupied Class 9 building

Table 11 Proposed Prescriptive Design for Evaluation

Parameter	Enhanced Provisions - Community Bushfire Refuge requirements
Separation from all classified vegetation	Radiant heat flux exposure not exceeding $10kW/m^2$
Separation between buildings	10m minimum or; FRL of 60/60/60 and any openings suitably protected or; radiant heat flux not exceeding $10kW/m^2$
Separation distance from allotment boundaries	10 m minimum, or; FRL of 60/60/60 and with any openings suitably protected, or; radiant heat flux not exceeding $10kW/m^2$.
Separation distance from car parking areas	10 m minimum, or; FRL of 60/60/60 and with any openings suitably protected, or; radiant heat flux not exceeding $10kW/m^2$.
Separation distance to other hazards e.g. gas bottles / medical gas storage etc.	heat flux not exceeding $10kW/m^2$ from all sources
Provision of non-combustible paths around building	1.5m wide around the perimeter of the refuge.
Max permitted radiant heat flux from bushfire on exposed building elements	Maximum $10kW/m^2$
Special access provisions to buildings	Access pathways should be readily identifiable and have a relatively even surface with a minimum clear width of 1m

Parameter	Enhanced Provisions - Community Bushfire Refuge requirements
External areas where occupants may be exposed to radiant heat flux from fire front	Maximum radiant heat flux of 1 kW/m^2. (assumed to exclude contribution from the sun)
Internal tenability through duration of occupancy	A mechanical air-handling system must be provided to maintain adequate air quality and temperatures below 30°C Max air temp limit 45°C (if air conditioning fails) Mean air temp limit 39°C (if air conditioning fails) Maximum internal surface temp 60°C
External Envelope	External envelop shall be non-combustible and comply with the AS 3959 construction requirements for BAL 19 or greater. Resistance to wind loads and collapsing trees shall be addressed as part of the structural design
Vehicular Access	Access roads shall be designed, constructed and maintained to a standard not less than a Modified 4C Access Road. A Modified 4C Access Road is an all-weather road which complies with the Australian Road Research Board "Unsealed Road Manual - Guidelines to good practice",3rd Edition, March 2009 as a classification 4C Access Road and the following modified requirements: Single lane private access roads less than6 m carriageway width must have20m longpassingbaysof6 m carriageway width, not morethan100mapart; A private access road longer than 100 m, must be provided with a driveway encircling the building or a hammerhead "T" or "Y" turning head4 m wide and8 m long, or a trafficable circular turning area of 10 m radius; Culverts and bridges must be designed for a minimum vehicle load of 20 tonnes; and Vegetation must be cleared for a height of 4 m, above the carriageway, and 2 m each side of the carriageway.
External manual firefighting provisions	Coverage of the perimeter of the refuge for a distance of 10m perpendicular to the perimeter shall be provided. A non-combustible water tank connected to a pump with sufficient back-up power to supply water to hose reels. Water tank capacity to be determined by the appropriate authority
Emergency Power Supply	Diesel powered generator and associated fuel storage to be provided. Generator capacity to be determined by the appropriate authority. Diesel fuel storage capacity and location to be determined by the appropriate authority.

These prescriptive measures were adopted as the basis for trial designs and were evaluated by quantitative analysis as described in Section 6 of this report. Further changes were made to these prescriptive requirements if determined to be necessary during the quantitative analysis.

6. Quantitative Analysis

6.1. Overview of Analysis

The analysis has been undertaken following the general principles of the draft verification method GV5 which is intended to be included in the NCC 2019 and is reproduced in Appendix B and the draft performance requirement GP 5.2 which was developed as part of this project and is summarised in Section 5.3.2. Since exposure of a generic building is being considered it is not appropriate to adopt the GV5 option of a complex analysis method because details of the frequency of ignition and process of fire spread through the surroundings to the Class 9b building will vary between facilities. Therefore, the simple method has been adopted with modifications where appropriate to address a generic solution.

The buildings have been classified as having Importance Level 4 which equates to a 1 in 200-year weather event. The FFDI was derived from historic data using the "Generalised Extreme Value" probability density function (GEV) to predict the 1 in 200-year weather exposures and compared to shorter exposure periods as described in Section 6.2. Four references cases were then selected based on the derived FFDI values that corresponded with Fire Danger Ratings and commonly specified FFDI values.

In Section 6.3, approximate separation distances were calculated to ensure a 10kW/m^2 radiant heat flux exposure threshold was not exceeded for a 20° downslope and level / upslope cases and compared to a separation distance for a 12.5kW/m^2 threshold based on vegetation classified as forest (representing the most severe exposure for evaluation) for the reference cases. Modelling approaches defined in AS 3959[4] were generally adopted.

Ember attack can extend the risk to buildings beyond the separation distance required to maintain a heat flux below 10kW/m^2 particularly for the case of forest fires with hazardous bark types or in the case of pine plantations where the impact of burning pine needles can be treated as an Extreme Hazard bark rating. Separation distances were calculated in Section 6.3 based on the statistical data provided by Kilinc [44]

Analyses are also included in this chapter relating to:

- Fire Spread from adjacent structures and other hazards
- Fire Brigade Intervention / Manual Suppression
- Internal Building Layouts and general internal fire protection measures
- Internal tenability conditions

Event trees were constructed to evaluate consequences using supporting data from various bushfire investigations, tests and analyses to justify the inputs and the results compared against the acceptance criteria of a 10% probability of ignition as specified by the proposed draft bushfire verification method.

6.2. Derivation of FFDI Values

A Class 9 building housing vulnerable occupants for which full evacuation before a bushfire event is not practicable has been classified as having an Importance Level 4 which equates to a 1 in 200 Annual Probability of Exceedance (APE) for a weather event

The Generalised Extreme Value probability density function (GEV) has been adopted to predict the APE of 1 in 200 year for weather exposures using the coefficients derived by Douglas [45-48] which are summarised in Table 12 and

Table 13. Using the following relationship;

$FFDI = a.Log_e(R)+b$
where;
a and b are the constants derived by regression analysis assuming a GEV function
R is the return period – years (corresponding to an APE).

The constants in Table 12 were back calculated from quoted FFDIs for return periods of 1:25 and 1:50 years. The constants were then used to calculate the FFDIs for APE of 1 in 200. The results are shown in

Table 14.

Table 12 Constants derived from GEV and Regression Analyses for FFDI Return periods

State	Station	a	b
Victoria	Bendigo	14.43	44.56
	Melbourne	5.77	86.42
	Orbost	25.97	6.41
	Albury / Wodonga	10.10	63.49
	Mt Hotham	8.66	8.14
Tasmania	Hobart	10.10	32.49
	Launceston	2.89	28.71
WA	Perth	5.77	58.42
SA	Adelaide	7.21	53.78
Queensland	Brisbane	11.54	50.85

Table 13 Constants derived from GEV and Regression Analyses for FFDI Return periods for Weather Districts in NSW.

District	Station	a	b
1. Far North Coast	Grafton	13.99	46.63
2. North Coast	Coffs Harbour	18.22	24.29
3. Greater Hunter	Williamtown	12.68	55.53
4. Greater Sydney	Sydney Ap	10.62	54.87
5. Illawarra/South Coast	Nowra	16.29	49.3
6. Far South Coast	Batemans Bay	14.69	38.71
7. Monaro-Alpine	Cooma	7.091	51.22
8. ACT	Canberra AP	13.56	49.63
9. Southern Ranges	Goulburn	10.96	61.92
10. Central Ranges	Bathurst	8.693	48.38
11. New England	Armidale	7.723	21.75
12. Northern Ranges	Tamworth	14.57	53.84
13. North Western	Moree	16.92	48.97
14. Upper Central West Plains	Coonamble	22.21	59.5
15. Lower Central West Plains	Dubbo	13.22	55.61
16. Southern Slopes	Young	5.667	56.84
17. Eastern Riverina	Wagga Wagga	15.98	65.88
18. Southern Riverina	Deniliquin	13.63	76.88
19. Northern Riverina	Hay	16.93	48.98
20. South Western	Mildura	14.78	76.91
21. Far Western	Cobar	13.07	60.73

Table 14 Maximum FFDIs for APEs for various weather stations

Station	APE 1 in (x)						
	1	5	12.5	25	50	100	200
Bendigo	45	68	81	91	101	111	121
Melbourne	86	96	101	105	109	113	117
Orbost	6	48	72	90	108	126	144
Albury / Wodonga	63	80	89	96	103	110	117
Mt Hotham	8	22	30	36	42	48	54
Hobart	32	49	58	65	72	79	86
Launceston	29	33	36	38	40	42	44
Perth	58	68	73	77	81	85	89
Adelaide	54	65	72	77	82	87	92
Brisbane	51	69	80	88	96	104	112
Grafton	47	69	82	92	101	111	121
Coffs Harbour	24	54	70	83	96	108	121
Williamtown	56	76	88	96	105	114	123
Sydney Ap	55	72	82	89	96	104	111
Nowra	49	76	90	102	113	124	136
Batemans Bay	39	62	76	86	96	106	117
Cooma	51	63	69	74	79	84	89
Canberra AP	50	71	84	93	103	112	121
Goulburn	62	80	90	97	105	112	120
Bathurst	48	62	70	76	82	88	94
Armidale	22	34	41	47	52	57	63
Tamworth	54	77	91	101	111	121	131
Moree	49	76	92	103	115	127	139
Coonamble	60	95	116	131	146	162	177
Dubbo	56	77	89	98	107	116	126
Young	57	66	71	75	79	83	87
Wagga Wagga	66	92	106	117	128	139	151
Deniliquin	77	99	111	121	130	140	149
Hay	49	76	92	103	115	127	139
Mildura	77	101	114	124	135	145	155
Cobar	61	82	94	103	112	121	130

To provide a useful benchmark, domestic dwellings are classified as importance level 2 with a corresponding APE of 1 in 50.

Four reference cases were selected for further analysis which approximated to the Fire Danger Ratings categories and AS 3959 FFDI levels used to ascertain construction levels using a 1:200 APE as shown in Table 15. The shaded cells show the FFDI values adopted for analysis.

Table 15 References Cases for Analysis

Case	Fire Danger Rating for APE of 1 in 50	Nearest AS3959 FFDI value	FFDI for APE 1:50	FFDI for APE 1:200	Source
1	Very High	50	56	65	Average value for Hobart and Launceston
2	Severe	80	79	89	Cooma slightly above range but similar to AS3959 Category FDI 80
3	Extreme	100	101	121	Bendigo & Grafton nearest values to FFDI of 99 and similar to AS3959 Category FDI 80
4	Code Red	-	135	155	Mildura – Highest value for which data available and comparable to Black Saturday

Note the 1:50

6.3. Calculation of Separation Distances to Limit radiant heat

The separation distances required to maintain maximum incident radiant heat flux levels from the assumed fire front below critical thresholds were calculated using Method 2 of AS 3959. The fire intensity was also calculated to provide an input for the analysis of ember attack.

The inputs used are summarised below:

Vegetation Classification	Forest
Surface fuel	25 t/ha
Overall fuel	35t/ha
Heat of combustion	18600 kJ/kg
Flame front width	100m
Flame temperature	1090K
Flame Emissivity	0.95
Ambient temperature	35°C
Relative Humidity	25%

The results are presented in Table 16 and Table 17.

Table 16 Calculated Separation Distances - 20° Downslope

FFDI	Fire Intensity - MW/m	Distance from the predominant vegetation class – m	
		Heat Flux < 10kW/m^2	Heat Flux < 12.5kW/m^2
155	238	140	127
121	185	122	111
100	153	109	98
89	135	102	91
80	122	96	86
65	99	86	76
50	76	74	65

Table 17 Calculated Separation Distances Level / Upslope

FFDI	Fire Intensity - MW/m	Distance from the predominant vegetation class – m	
		Heat Flux < 10kW/m^2	Heat Flux < 12.5kW/m^2
155	84	71	62
121	66	62	54
100	54	56	48
89	48	52	45
80	43	49	42
65	35	44	37
50	27	38	32

The separation distances in Table 16 and Table 17 significantly exceed the calculated flame lengths and therefore they will inherently address the risk of direct flame contact from the fire front. For downslopes greater than 20° the potential for flame adhesion and extension due to reduced air entrainment increases and detailed analysis of the particular site would be required for these situations on a case by case basis.

6.4. Calculation of Separation Distances to Reduce the Risk of Loss from Ember Attack

AS 3959 adopts a simplistic approach to ember protection by prescribing measures to reduce the risk of ignition from embers for properties within 100m of the unmanaged vegetation (forest for the scenarios under consideration). However, approximately 20% of house losses occur more than 100m from the interface with the unmanaged vegetation,

Class 9 buildings housing vulnerable occupants may need to provide shelter to the occupants during a bushfire event and therefore a higher survival rate for buildings is necessary. The Bushfire Verification Method also requires that the probability of ignition should not exceed 10%.

The required separation distance from the forest before mitigation measures are necessary has therefore been calculated based on the statistical analysis of Bushfire Penetration into Peri-urban areas undertaken by Kilinc[44]

The method estimates the probability of house loss taking into account of the bark hazard, fire intensity and distance from the forest. The method is based on observed losses and therefore the majority of losses would be from buildings without specific measures to reduce the fire risk.

Since the extent of ember attack would depend upon a relatively large area of vegetation it was considered reasonable to base the fire intensity on the no slope / upslope condition and the cases were grouped to Fire Intensity levels as shown below:

- Reference Case 1 – Fire intensity 30 MW/m
- Reference Case 2 – Fire intensity 50 MW/m
- Reference Case 3 and 4 – Fire intensity 100MW/m
- The Bark Hazard Ratings are determined in accordance with Hines [49]

Copies of Design Charts from Kilinc[44] are provided in Appendix C.

The results are summarised in Table 18. For Low Bark Hazards the probability of loss at 100m from the forest is less than 0.1 for all Intensities.

Table 18 Probability of loss of an unprotected building at various distances from forest for variations in Fire Intensity and Bark Hazard

Reference case	Intensity-MW/m	Prob of loss	Distance from forest -m (for bark hazard rating)		
			Medium / High	Very High	Extreme
3 & 4	100	0.7	-	34	102
		0.6	50	87	155
		0.5	98	135	203
		0.4	147	184	252
		0.3	200	237	305
		0.2	265	302	369
		0.1	362	399	467
		0.05	451	489	556
2	50	0.6	-	15	83
		0.5	26	63	131
		0.4	75	112	180
		0.3	128	165	233
		0.2	193	230	298
		0.1	290	327	395
		0.05	379	417	484
1	30	0.5	-	10	78
		0.4	22	59	127
		0.3	75	112	180
		0.2	140	177	245
		0.1	237	274	342
		0.05	326	364	431

Based on a review of Table 18 in order to satisfy the Bushfire Verification Method, protection against embers would be required for buildings more than 100m from the forest type vegetation for Class 9 buildings housing vulnerable occupants.

A simple (and reliable) approach for a DTS solution to address the above hazard is to apply the prescriptive requirements specified in Table 11 to all Class 9 buildings housing vulnerable occupants located within a bushfire prone area unless a specific performance solution is developed.

6.5. Fire Spread from adjacent Structures and Hazards other than Vegetation

The NCC provides a verification methods CV1 and CV2 to assess the risk of fire spread between buildings. These are summarised below;

“CV1

Compliance with CP2(a)(iii) to avoid the spread of fire between buildings on adjoining allotments is verified when it is calculated that—

(a) a building will not cause heat flux in excess of those set out in column 2 of Table CV1 at locations within the boundaries of an adjoining property set out in column1 of Table CV1 where another building may be constructed; and

(b) when located at the distances from the allotment boundary set out in column1 of Table CV1, a building is capable of withstanding the heat flux set out in column 2 of Table CV1 without ignition.

Table CV2

Column 1	Column 2
Location	**Heat Flux (kW/m^2)**
On boundary	80
1m from boundary	40
3m from boundary	20
6m from boundary	10

CV2

Compliance with CP2(a)(iii) to avoid the spread of fire between buildings on the same allotment is verified when it is calculated that a building—

(a) is capable of withstanding the heat flux set out in column 2 of Table CV2 without ignition; and

(b) will not cause heat flux in excess of those set out in column 2 of Table CV2, when the distance between the buildings is as set out in column1of Table CV2.

Table CV2

Column 1	Column 2
Distance between buildings	**Heat Flux (kW/m^2)**
0m	80
2m	40
6m	20
12 m	10

"

Since an NCC compliant building constructed on the same site is required to limit the heat flux to 10kW/m^2 at a separation distance of 12m it is considered appropriate to increase the default separation distance from 10m to 12m to maintain compatibility with CV2.

The 10kW/m^2 incident heat flux limit will still be retained as an option to allow lesser distances to be determined by calculation for smaller structures or structures of fire-resistant construction with a low proportion of openings in the building envelope.

Typically the 12m separation distance will include a significant safety margin particularly for smaller structures as demonstrated by a test performed on a 1960s house predominately clad in weatherboards to window sill height and then asbestos reinforced cement sheet to the eaves reported by Bowditch [50].

Peak radiant heat measurements were;

- 70kw/m^2 at 2m
- 16kw/m^2 at 4m
- 8kw/m^2 at 6m

However, the results will be sensitive to the internal fire load, opening sizes and configurations, construction materials and methods and weather conditions and therefore it is reasonable to adopt a conservative DTS separation distance which can be modified based on a specific assessment of a site.

6.6. Fire Brigade Intervention / Manual Suppression

Access to the site and external firefighting equipment are required to be provided to facilitate fire brigade intervention. Whilst it is expected that local emergency planning would identify the protection of Class 9 buildings housing vulnerable occupants as a priority for the local fire brigade the nature of bushfires is such that resources could be allocated to other locations at the time the fire front approaches the building. The event tree analysis will therefore evaluate the risk of ignition with and without fire brigade intervention. A high probability of successful fire brigade (manual) suppression has been assumed taking account of the dedicated firefighting facilities and other measures that minimise the risk of building ignition.

The likelihood of successful manual suppression would also be increased if the Class 9 building is also used as a community refuge since additional people may be available to undertake limited firefighting before and after the arrival of the fire front.

Refer Section 6.9 for the event tree analysis.

6.7. Internal Building Layout / Internal Fire protection measures

The primary fire safety objectives are to prevent a bushfire penetrating the building envelope and causing ignition and maintaining tenable conditions within the building. The quantitative analysis undertaken has focussed on these objectives.

However, Class 9a hospitals and Class 9c aged accommodation buildings include significant internal fire protection measures that may have a significant impact on the safety of vulnerable occupants in circumstances where fire spread does occur to the inside of the building or tenable conditions cannot be maintained throughout the building.

Class 9c buildings and some 9a buildings will have an internal automatic fire sprinkler system installed which may control or suppress an internal fire. However, the fire sprinkler system may be ineffective if multiple ignitions occur or a fire develops in an unprotected concealed space.

In addition, Class 9a and Class 9c buildings require fire or smoke separation as indicated in the schematic layouts shown in Figure 19 and Figure 20.

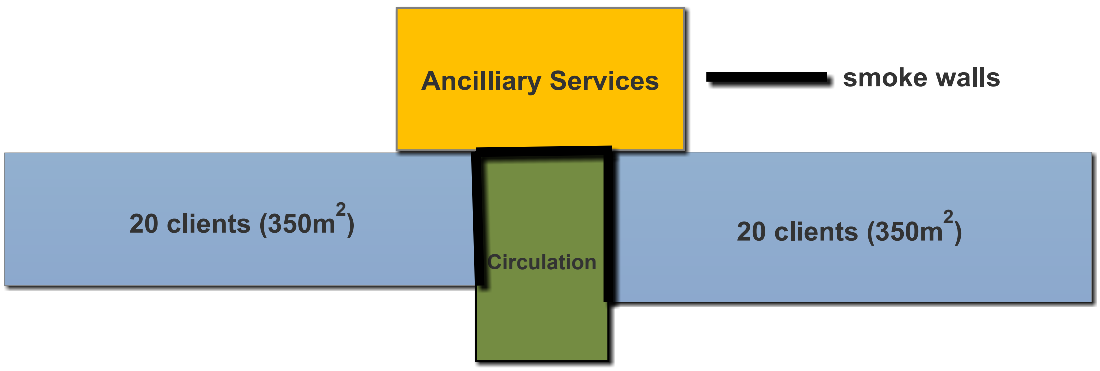


Figure 19 Schematic Layout of Class 9c single storey building

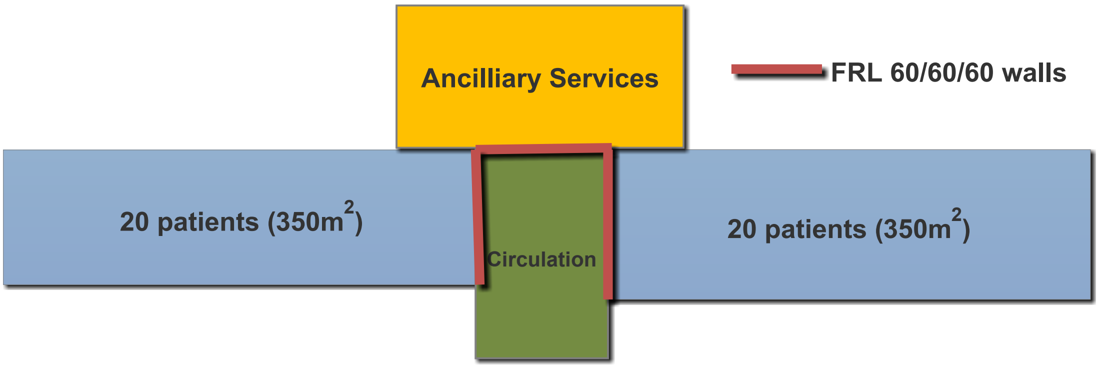


Figure 20 Schematic Layout of Class 9a single storey building

The layouts provide the opportunity for occupants to be consolidated within a smoke or fire sub compartment if the building envelope is breached and whilst tenability within the building may not be maintained indefinitely there will be a greater opportunity for intervention and potential evacuation after the fire front passes. Having separate zones also provides the opportunity for independent air conditioning systems to be provided such that if one unit fails, occupants can be consolidated into another part of the building.

The impact of the above features has not been quantified since they are not primary bushfire protection systems and will only be used in extreme circumstances if the primary bushfire safety strategy is unsuccessful.

A typical schematic internal layout for a Class 9b school building is shown in Figure 21. It can be observed that there is unlikely to be significant internal compartmentation and automatic fire sprinkler protection is not required by the NCC and reliance is placed on the primary bushfire safety strategy.

Figure 21 Schematic Layout of Class 9b single storey building

Smoke detection systems will be provided in most Class 9 buildings and if there is a fire in close proximity to the building the alarm could be activated making communication difficult and potentially increasing the stress to which the occupants are exposed. It is suggested that these matters be discussed with the fire authorities and designers and operational policies established which may require additional features to be provided for the detection systems.

6.8. Maintaining Tenability for Vulnerable Occupants

Occupants of Class 9 buildings can be more vulnerable to heat stroke and the effects of smoke infiltration and for healthcare facilities it may be critical to maintain power to key items of equipment.

The design of general emergency power supplies (generators) and air-conditioning systems with capabilities to recycle air to minimise smoke ingress generally lie outside the scope of the NCC but may be critical to a successful outcome.

The proposed performance requirement requires tenability to be addressed and indicates matters for consideration.

The proposed prescriptive requirements include the following provisions to address tenability;

A mechanical air-handling system must be provided to maintain adequate air quality and temperatures below 30°C
Max air temp limit 45°C (if air conditioning fails)
Mean air temp limit 39°C (if air conditioning fails)
Maximum internal surface temp 60°C

It should be noted that the above temperatures may place some vulnerable occupants at risk and they have therefore been modified to provide greater flexibility to allow the provisions to be adjusted for a specific facility and the default temperatures have also been reduced since they can be varied

A mechanical air-handling system must be provided to maintain adequate air quality and temperatures. Typically, the air handling system should be capable of being adjusted to full recycling of air for limited periods to avoid introduction of smoke and should be capable of maintaining internal air temperatures below 25°C.

If the air conditioning fails -the design of the building envelope should maintain max internal air temperatures below 39°C and limit maximum internal surface temperatures of the building to 60°C.

As far as practicable the internal building space should be split into two or more sub-compartments on each level served by independent mechanical air-handling systems to allow for occupants to move to an airconditioned area if an air conditioning unit fails. The design should address the risk of automatic shutdown of the systems if smoke detectors are activated by low concentrations of smoke from external sources.

6.9. Event Tree Analysis

Appendix D includes an event tree analysis that was undertaken as part of a study to inform decisions regarding Inputs and Acceptance Criteria for the National Construction Code Verification Method for Buildings in Bushfire Prone Areas[36] (refer Appendix B for a current draft of the Verification Method).

The Appendix D event trees form a useful benchmark and basis for the derivation of the proposed solutions and analysis of Class 9 buildings housing vulnerable occupants. For dwellings the probability of house loss remained high despite the application of construction measures based on AS 3959 due predominantly to low levels of compliance and maintenance of fire protection measures and vegetation, the vulnerability of the designs to non-compliances and lack of manual suppression activities.

The level compliance is expected to be significantly higher for Class 9 buildings with greater oversight being provided during the design and operation of the facilities by health, education building and planning authorities within the State and Territory Administrations which include in some cases requirements for annual inspections and audits.

In addition, the proposed prescriptive requirements have been derived with the intention of making the provisions less susceptible to design and installation errors through the introduction of safety factors and redundancies in the design. Typical examples of this approach are;

- Limiting incident heat flux to 10kW/m^2 which is below the critical heat flux for piloted ignition for many combustible materials and unlikely to cause significant deterioration of materials used for the construction of the building envelope.
- Specification of BAL 19 construction requirements, non-combustible building envelope materials notwithstanding the 10kW/m^2 incident heat flux limitation. These requirements provide a level of protection against small volumes of burning debris and burning embers that may collect around a building and incorporate features to protect door and window openings from ingress of embers in addition to resistance to radiant heat fluxes up to 19kW/m^2.
- Specification of non-combustible pathways 1.5m around a building reducing the risk of garden beds (plants) and mulch in close proximity to the building façade
- Limiting exposure of external equipment and separation distances of 10m from other hazards
- Additional provisions for firefighting and fire brigade access

Event trees for the Class 9 buildings have been constructed and are included in Appendix E together with an explanation of the changes from the event trees used for Class 2 buildings. The findings of the risk analysis for the proposed Class 9 and Class 2 buildings evaluated previously are summarised in Table 19.

Table 19 Proportion of Losses for proposed Class 9 building and Class 2 buildings from previous study based on AS 3959 requirements

Condition	Proportion of losses for Class 9 buildings	Proportion of losses for Class 2 buildings
No Suppression	10%	71%
Manual Suppression	1%	35%
No Suppression (full compliance at end of construction and maintained through building life)	1%	16%
Suppression (full compliance at end of construction and maintained through building life)	0.1%	8%

The proposed Bushfire Verification Method states that compliance with Performance Requirement GP5.1 is verified if the ignition probability for a building exposed to a design bushfire does not exceed 10%. This criterion is assumed to apply to the case including manual suppression since the building will be occupied and is therefore satisfied by an order of magnitude (1% compared to the acceptable limit of 10%). This is considered appropriate having regard for the vulnerability of occupants, community sensitivity to societal risk involving large loss of life and limited available data notwithstanding the adoption of a 1 in 200 APE weather conditions.

The comparison with Class 2 buildings and the fully compliant scenarios also provide a useful sensitivity analysis. Not surprisingly the outcomes are very sensitive to the levels of compliance and maintenance of equipment and vegetation through the life of the building with probabilities of loss varying from 1% for a fully compliant Class 9 building to 71% for a poorly maintained class 2 building ignoring manual suppression. The probability of loss of 10% for a Class 9 building with high levels of compliance appears reasonable against these two extreme values.

For the class 2 buildings data was available on losses with and without occupants in attendance and the probability of loss is approximately halved if people are in attendance to address ignitions before they take hold. Since substantial firefighting provisions have been provided and there is a high probability that fire brigade resources could be made available to protect a Class 9 building housing vulnerable occupants, a 90% probability of successful manual suppression was included. The difference between a 50% probability of successful manual suppression and 90% probability is a factor of 5 indicating that the results are sensitive to the assumed effectiveness of manual suppression.

6.10. Analysis Check List

Table 20 provides an analysis check list to ensure relevant matters have been considered providing a quality check for the report.

Table 20 Analysis Check List

Parameter for consideration	Approach / value	Comment
Building Importance Level	4	Large numbers of vulnerable people in critical building -evacuation not viable
APE for weather conditions	1:200	Simple method – for generic solution
Direct attack from airborne burning embers.	Minimum separation distance	Considered based on Statistical Analysis of Penetration into Peri-urban Areas – Kilinc [44]
Burning Debris and accumulated embers adjacent to a building element	AS 3959 specification of BAL Construction	AS3959 [4] Construction Requirements
Radiant Heat from Bushfire Front	AS 3959 approach	Separation distances checked based on FFDI, land slop, fuel load, distance etc
Direct Flame attack from Bushfire front	Direct attack avoided	Specification of separation distances and vegetation controls
Fire Weather	FFDI	1:200-year conditions estimated based on GEV distribution
Vegetation	AS 3959 method and Kilinc graphs adopted for ember attack	Forest considered, AS 3959 default fuel load assumed, burning behaviour including crown fires and risk of ember attack considered inherently in selected methods
Distance from vegetation	Min separation distances specified	Distances checked based on AS 3959 method and Kilinc graphs
Topography	Inherently addressed in AS 3959 and Kilinc graphs	Related to fire line intensity

Parameter for consideration	Approach / value	Comment
Ignition of adjacent buildings, building elements, plants, mulch and other materials	Management requirements and separation distances and BAL / FRL specification	Analysis of adjacent structures undertaken by reference to CV1, CV2 and test data
Effective size of fire front	100m length of fire front burning at full intensity assumed	AS 3959 method
Exposure periods to direct attack	Based on AS 1530-8.1 [51] exposure profile. Exposure assumed to be at least 30 minutes for an adjacent structure	Ember attack periods have been assumed to be for extended periods and internal tenability is required to be maintained throughout the bushfire emergency.
Flame height, tilt and building height and heat flux is calculated based on the most onerous flame angle and receiver angle	AS 3959 approach	Inherently addressed in calculation of incident heat flux by AS 3959
Adhesion of flame	AS 3959 approach	Risk reduced limiting slope to 20° and AS 3959 approach of determining most severe flame angle for calculation of building exposure
Probability of non-complying construction	Event tree analysis	Management in use expectations specified
Probability of critical aspects not being fully functional during the life of the building	Event tree Analysis	Management in use expectations specified
Inclusion of safety factors	Inherent	Generally inherent safety factors included by conservative assumptions and increased separation distance
Sensitivity analysis	Event tree Analysis	Sensitivity analysis included
Probability of ignition	Event tree Analysis	
Vehicular Access	Prescriptive requirements included	Based on Tasmanian requirements
Fire Fighting Provisions	Prescriptive requirements included	Reference to fire brigades required to ensure provisions are appropriate.
Tenable conditions for occupants	Generally addressed by prescriptive solution	number of occupants to be accommodated within the refuge, duration of occupancy, safe access within the site to the refuge, (including carpark areas), as well as occupant egress after the bushfire event; and occupant tenability within the refuge for the duration of occupancy before, during and after the bushfire event are prescribed

7. Conclusions

A quantified risk assessment has been undertaken on behalf of the Australian Building Codes Board (ABCB) relating to the risk to vulnerable occupants in Class 9 Buildings Associated with Bushfire Attack in designated Bushfire Prone Areas based on, amongst other things:

- Historical data of losses of dwellings and people
- Application of the current NCC 2016 Deemed-to-Satisfy provisions applicable to the relevant building types (including Amendment 1)
- Consideration of the impact of State and territory variations / approval and referral mechanisms

It was found that vulnerable people are exposed to significantly higher risks than the general population during a bushfire event. It may not be practicable to prohibit construction of Class 9 buildings housing vulnerable occupants in bushfire prone areas but in some cases, this could be a valid, reasonable and preferred solution which would be generally managed through the planning process. Where existing communities need to be served by schools and health-care facilities and locating these services at substantial distances away from communities may increase other risks such as transport risks and health risks due to delayed treatments in addition to disadvantaging the local communities, construction of Class 9 buildings housing vulnerable occupants within Bushfire Prone Areas will be required. Early evacuation strategies may be appropriate and the preferred option for some Class 9 buildings such as schools.

The following proposed performance requirement for Class 9 buildings housing vulnerable occupants was developed

GP5.2 Draft

A Class 9 building housing vulnerable occupants that may be used as a refuge for the vulnerable occupants (and other people) that is constructed in a designated bushfire prone area must, to the degree necessary—

(a) be designed and constructed to reduce the risk of ignition from a bushfire, appropriate to the—
(i) potential for ignition caused by burning embers, radiant heat or flame generated by a bushfire; and
(ii) intensity of the bushfire attack on the building; and
(b) be provided with vehicular access to the site to assist firefighting and emergency personnel defend the building or evacuate occupants; and
(c) be provided with access at all times to a sufficient supply of water for firefighting purposes on the site.
(d) provide a tenable environment for occupants during the passage of external untenable conditions arising from a bushfire event, appropriate to the –

x. location of the refuge relative to fire hazards including-
   bb) predominant vegetation; and
   ee) adjacent buildings, structures and movable objects; and
   ff) car parking area/s and allotment boundaries; and
   gg) other combustible materials;
xi. number of occupants to be accommodated within the refuge, and
xii. duration of occupancy, and
xiii. bushfire intensity having regard to the bushfire attack level; and
xiv. intensity of potential consequential fires, and
xv. safe access within the site to the refuge, (including carpark areas), as well as occupant egress after the bushfire event; and

xvi. occupant tenability within the refuge for the duration of occupancy before, during and after the bushfire event; and

xvii. combined effects of structural, fire exposure and actions to which the refuge may reasonably be subjected; and

xviii. provision of fire-fighting equipment and water supply to facilitate protection of the refuge

Verification Method GV5 will require some adjustment if it is to be applied to the draft GP5.2 presented above.

A proposed prescriptive solution was adapted from the Design and Construction of Community Bushfire Refuges Handbook criteria with modifications appropriate to an occupied Class 9 building as determined in this report. The solution is summarised in Table 21.

Event trees were constructed to evaluate consequences using supporting data from various bushfire investigations tests and analyses to justify the inputs and the results compared against the acceptance criteria of a 10% probability of ignition as specified by the proposed draft bushfire verification method.

This criterion was assumed to apply to the case including manual suppression since the building will be occupied and provisions for firefighting are provided. Therefore, the acceptance criterion is satisfied with a safety factor of an order of magnitude (1% compared to the acceptable limit of 10%). This is considered appropriate having regard for the vulnerability of occupants, community sensitivity to societal risk involving large loss of life and limited available data on which to estimate some probabilities, notwithstanding the adoption of a 1 in 200 APE weather conditions.

Separation distances and protection from other buildings have been addressed by the above provisions for Class 9 buildings containing vulnerable occupants and therefore it is reasonable for buildings that will not be occupied during a bushfire event, to be protected in accordance with the NCC less stringent requirements that currently apply to Class 2 and 3 buildings if the building does not provide critical services to occupied Class 9 buildings and does not serve other critical community functions.

Table 21 Proposed Prescriptive Requirements for Class 9 Buildings Housing Vulnerable Occupants

Parameter	Enhanced Provisions - Community Bushfire Refuge requirements
Separation from all classified vegetation	Radiant heat flux exposure not exceeding 10kW/m^2
Separation between buildings	12m minimum or; FRL of 60/60/60 and any openings suitably protected or; radiant heat flux not exceeding 10kW/m^2
Separation distance from allotment boundaries	10 m minimum, or; FRL of 60/60/60 and any openings suitably protected, or; radiant heat flux not exceeding 10 kW/m^2.
Separation distance from car parking areas	10 m minimum, or; FRL of 60/60/60 and with any openings suitably protected, or; radiant heat flux not exceeding 10 kW/m^2.
Separation distance to other hazards e.g. gas bottles / medical gas storage etc.	Appropriate measures for risk; Full fire separation appropriate to the hazard (but not less than FRL 60/60/60) or separation distance to maintain heat flux not exceeding 10kW/m^2 from all sources (acting simultaneously)
Provision of non-combustible paths around building	1.5 m wide around the perimeter of the building.
Maximum permitted radiant heat flux from bushfire on exposed building elements	10 kW/m^2
Special access provisions to buildings	Access pathways should be readily identifiable and have a relatively even surface with a minimum clear width of 1m
External areas where occupants may be exposed to radiant heat flux from fire front	Maximum incident radiant heat flux from the fire front not greater than 1 kW/m^2. (above the background solar radiant heat).
Internal tenability through duration of occupancy	A mechanical air-handling system must be provided to maintain adequate air quality and temperatures. Typically, the air handling system should be capable of: • being adjusted for full recycling of air for limited periods to avoid the introduction of smoke and • maintaining internal air temperatures below 25°C If the air conditioning fails -the design of the building envelope should • maintain max internal air temperatures below 39°C and • limit maximum internal surface temperatures to 60°C As far as practicable, the internal building space should be split into two or more sub-compartments on each level with each sub-compartment served by independent mechanical air-handling systems to allow for occupants to be moved to an airconditioned area if an air conditioning unit fails. The system design should account for activation of smoke detectors from low concentrations of smoke from external sources to ensure that the air conditioning and other essential services can remain operational.

Parameter	Enhanced Provisions - Community Bushfire Refuge requirements
External Envelope	The external envelop shall be non-combustible and comply with the AS 3959 construction requirements for BAL 19 or greater. Resistance to wind loads and collapsing trees shall be addressed as part of the structural design
Alarm System Control	Operational policies should be established to silence the alarm system if activated by smoke of a bushfire close to the building. This may require additional features to be provided for the detection systems within the building. The design and procedures should be developed in conjunction with the designers, fire authorities and relevant authorities.
Signage and Fire Safety Plan	Signage should provide warning occupants not to store combustible materials under buildings or adjacent to buildings and the bushfire safety plan for the building should be documented in a manual and provided to the building owners and operators.
Vehicular Access	Access roads shall be designed, constructed and maintained to a standard not less than a Modified 4C Access Road. A Modified 4C Access Road is an all-weather road which complies with the Australian Road Research Board "Unsealed Road Manual -Guidelines to good practice",3rd Edition, March 2009 as a classification 4C Access Road and the following modified requirements: Single lane private access roads less than 6 m carriageway width must have20m long passing bays of 6 m carriageway width, not more than 100m apart; A private access road longer than 100 m, must be provided with a driveway encircling the building or a hammerhead "T" or "Y" with a turning head 4 m wide and 8 m long, or a trafficable circular turning area of 10 m radius; Culverts and bridges must be designed for a minimum vehicle load of 20 tonnes; and Vegetation must be cleared for a height of 4 m, above the carriageway, and 2 m each side of the carriageway.
External manual firefighting provisions	Coverage of the perimeter of the refuge for a distance of 10m perpendicular to the perimeter shall be provided with a non-combustible water tank connected to a pump with sufficient back-up power / fuel to supply water to hose reels. Water tank capacity and backup power / fuel supplies should be determined by the appropriate fire authority
Emergency Power Supply	Diesel powered generator and associated fuel storage should be provided. Generator capacity should be determined by the appropriate authority. Diesel fuel storage capacity and location to be determined by the appropriate authority.

Appendix A. Acceptance Criteria for Community Bushfire Refuges

The following acceptance criteria have been extracted from the ABCB Handbook Design and Construction of Community Bushfire Refuges[18]

Table 22 Acceptance Criteria for Community Bushfire Refuges from ANCN 2014

Category	Design Consideration	Acceptance Criteria	Comment
Location of Refuge	Separation distance between a refuge and primary vegetation	Sufficient distance to avoid exposure to a radiant heat flux exceeding 10kW/m^2 from a combination of sources; OR Exposed construction of a refuge to have a minimum FRL of 60/60/60 and any openings suitably protected.	Separation reduces potential fire spread between primary vegetation and a refuge. 10 kW/m2 will enable fire-fighters wearing protective clothing to approach a refuge for a short period of time.
Location of Refuge	Separation distance between a refuge and adjacent buildings and structures	10m minimum to an adjacent building or substantial structure; OR Exposed construction of a refuge to have an FRL of 60/60/60 and any openings suitably protected; OR Sufficient distance to avoid exposure to a radiant heat flux exceeding 10kW/m^2 from a combination of sources.	Adjacent structures include sheds, carports etc. Separation or provision of fire-resisting construction reduces potential fire spread between adjacent buildings and a refuge.
Location of Refuge	Separation distance between a refuge and car parking areas and allotment boundaries	10 m minimum; OR Exposed construction of a refuge to have an FRL of 60/60/60 and with any openings suitably protected; OR Sufficient distance to avoid exposure to a radiant heat flux exceeding 10kW/m^2 from a combination of sources.	Separation or provision of fire-resisting construction reduces potential fire spread between adjacent buildings and a refuge.
Location of Refuge	Separation distance to other significant combustible materials	Sufficient distance to avoid exposure to a radiant heat flux exceeding 10kW/m2 from a combination of sources.	Potential fuel sources include vehicles, fences, gas storage bottles, liquid fuel or similar
Location of Refuge	Separation from adjacent minor hazards	1.5m wide on-ground non-combustible pathway around the perimeter of the refuge.	A non-combustible barrier/apron will reduce the potential for fire spread from external ground level sources.

Category	Design Consideration	Acceptance Criteria	Comment
Bushfire Intensity	Radiant heat flux on exposed building elements. (Also see criteria for access pathways below)	Maximum 10kW/m2 from a combination of sources.	Sufficient radiant heat flux will cause ignition of combustible materials and break materials such as glass.
Access to the community Bushfire Refuge	Main access doorways to be automatic opening when the building is operating as a refuge	Reference to text included	Community members should be able to access a refuge without delay when the building is operating as a refuge
Main Access Pathways	Surface of pathways leading from carpark areas and adjacent buildings	Surfaces must be non-combustible	Access pathways should be readily identifiable and have a relatively even surface
Main Access Pathways	Unobstructed width of pathways leading from carpark areas and adjacent buildings.	Minimum clear width of 1 m.	Vegetation adjacent to a pathway should not become a hazard to travel. Vegetation management procedures should be applied.
Main Access Pathways	Pathways used to hold people unable to be safely accommodated within a refuge	Exposure to a maximum radiant heat flux of 1 kW/m2.	Pathways should only be used to accommodate excess people. Human exposure to excessive radiant heat flux can result in severe burning of skin. People may require face-masks to reduce inhalation of excessive quantities of smoke.

Category	Design Consideration	Acceptance Criteria	Comment
Provision of Tenable Conditions	Duration of occupancy	Minimum 60 minutes.	The minimum period of occupation for which a tenable environment should be maintained. It is assumed that occupants will not close main access doors until exposure to untenable conditions is imminent. A refuge may be occupied for longer periods, either pre-bushfire attack or post-bushfire attack, in an open state i.e. with doors or windows open.
Provision of Tenable Conditions	Floor area	Minimum 0.75 m2 per person.	Minimum ‘floor area’ criterion addresses the relationship between the occupancy period and the number of occupants in the refuge.
Provision of Tenable Conditions	Volume	Minimum 1.2 m3 per person.	Minimum ‘volume’ criterion is intended to provide sufficient air for a maximum duration of 60 minutes. Design durations greater than 60 minutes will require a specific assessment of air supply.
Provision of Tenable Conditions	Interior air temperature or Interior mean Modified discomfort index (MDI) for 60 minutes	Maximum 45°C (Patterson et al. 2010). Maximum mean 39°C (Patterson et al. 2010).	A tenable environment within a refuge can be detrimentally affected by increased air temperature and relative humidity (refer to A.7.4). Internal temperatures ≤ 350C are preferable.
Provision of Tenable Conditions	Interior surfaces temperature	Maximum 60°C for readily accessible surfaces.	Interior surface temperatures can be estimated by exposure to design fire conditions. Typical surfaces are those which an occupant of a refuge would be able to touch. Guarding or insulating of materials may be required. Interior surface temperatures will influence interior air temperatures.

Category	Design Consideration	Acceptance Criteria	Comment
Provision of Tenable Conditions	Interior air toxicity	Construction materials forming part of a refuge that are likely to give off gas when exposed to temperatures exceeding 100°C must be tested to BS 6853 (1999) Appendix B2. Gases must be limited to: (a) carbon monoxide 30 ppm; (b) hydrogen chloride 1.0 ppm; (c) hydrogen bromide 0.5 ppm; (d) hydrogen fluoride 0.5 ppm; (e) hydrogen cyanide 1.0 ppm; (f) nitrogen dioxide 0.5 ppm; and (g) sulphur dioxide 2.5 ppm.	Materials used for construction of a refuge should not unduly influence the tenable environment within a refuge during occupation
Provision of Tenable Conditions	Ventilation	Natural ventilation must be provided by openings such as doors or other devices that, when open, have an aggregate open area of not less than 5% of the floor area of the refuge; or A mechanical air-handling system must be provided to maintain adequate air quality.	Refuges may require ventilation to ensure a tenable environment is provided. Ventilation may be used to supplement air supply and quality when external conditions are suitable. If a system serving the primary use of a refuge requires external air intake, it will be necessary to shut this system down when the refuge is sealed so that the potential for embers to enter the internal space is minimised.
External Envelope	Structural design	The structural design of a refuge must be in accordance with Volume One of the BCA. All loads and actions to which a refuge may reasonably be subjected must be considered, as necessary, for a building having an Importance Level not less than 3 as per BCA Volume One Table B1.2a.	The building is to be designed with regard to - (a) topography of the site; (b) dead loads; (c) live loads; (d) impact loads (e.g. collapsing trees); and (e) wind loads.

Category	Design Consideration	Acceptance Criteria	Comment
Signage	External signage	(a) A permanent sign made from durable materials must be fixed adjacent to the main access roadway on the allotment on which a refuge is located. (b) The sign shall be headed "COMMUNITY BUSHFIRE REFUGE" in red letters on a white background in letters at least 100 mm high. (c) The sign must include the following information in red letters at least 25 mm high; i. the distance to the refuge on the allotment; and ii. the general direction in which the refuge is located (using word	Some examples may be found in the Victorian Fire Service Commissioner's 'Community Fire Refuges' manual. A copy may be downloaded at the Fire Services Commissioner Victoria website (www.firecommissioner.vic.gov.au)
Signage	Internal signage	(a) A permanent sign made from durable materials must be fixed inside a refuge adjacent to the main access door. (b) The sign shall be headed "COMMUNITY BUSHFIRE REFUGE" in red letters at least 25 mm high on a white background. (c) The sign must include the following information in letters at least 20mm high - (d) the designed number of occupants; (e) the designed duration of occupation; (f) advice that increasing the designed number of occupants will decrease the maximum duration of occupation.	Some examples may be found in the Victorian Fire Service Commissioner's 'Community Fire Refuges' manual. A copy may be downloaded at the Fire Services Commissioner Victoria website (www.firecommissioner.vic.gov.au)
Capacity to Assess External Conditions	Viewing opening or window	Reference to text included	Prior to leaving a refuge, occupants will need to visually assess external conditions and a viewing opening, or window would be an appropriate mechanism.

Category	Design Consideration	Acceptance Criteria	Comment
Fire Fighting Equipment	Hose reels Water supply for hose reels	Coverage of the perimeter of the refuge for a distance of 10m perpendicular to the perimeter. A non-combustible water tank connected to a pump with sufficient back-up power to supply water to hose reels. Water tank capacity to be determined by the appropriate authority	The provision of hose reels will allow occupants to extinguish embers, pre-event and consequential fires presenting a hazard to the refuge
Sanitary Facilities	Sanitary facilities to be provided for occupants	Compliance with National Construction Code; or Supplementation of existing facilities with portable facilities for a refuge developed from an existing building.	The scope of sanitary facilities to be provided will relate to the designed number of occupants. Portable facilities may include sealable buckets.
Emergency Power Supply	Diesel powered generator Diesel fuel storage	Generator capacity to be determined by the appropriate authority. Diesel fuel storage capacity and location to be determined by the appropriate authority.	An emergency power supply is essential to provide power for lighting, mechanical ventilation, air-conditioning (if provided) and certain fire-fighting equipment. Diesel generator performance must be sufficient to enable the concurrent operation of emergency equipment for the designed duration of occupation of a refuge
Maintenance	Maintenance of fire safety and other essential design components	A refuge must be maintained in accordance with the regulations applicable in the State or territory in which it is located.	Refuges should be capable of performing as required at all times.

GV5 Buildings in bushfire prone areas

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(B) associated with hazardous facilities; or

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

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

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

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

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

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

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

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

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

(A) Direct attack from airborne burning embers.

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

(C) Radiant heat from a bushfire front.

(D) Direct flame attack from a bushfire front.

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

(i) fire weather; and

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

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

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

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

(vi) effective size of fire front; and

(vii) duration of exposure; and

(viii) flame height; and

(ix) flame tilt; and

(x) flame adhesion to sloping land; and

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

(f) The assessment process must include consideration of—

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

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

(iii) inclusion of safety factors; and

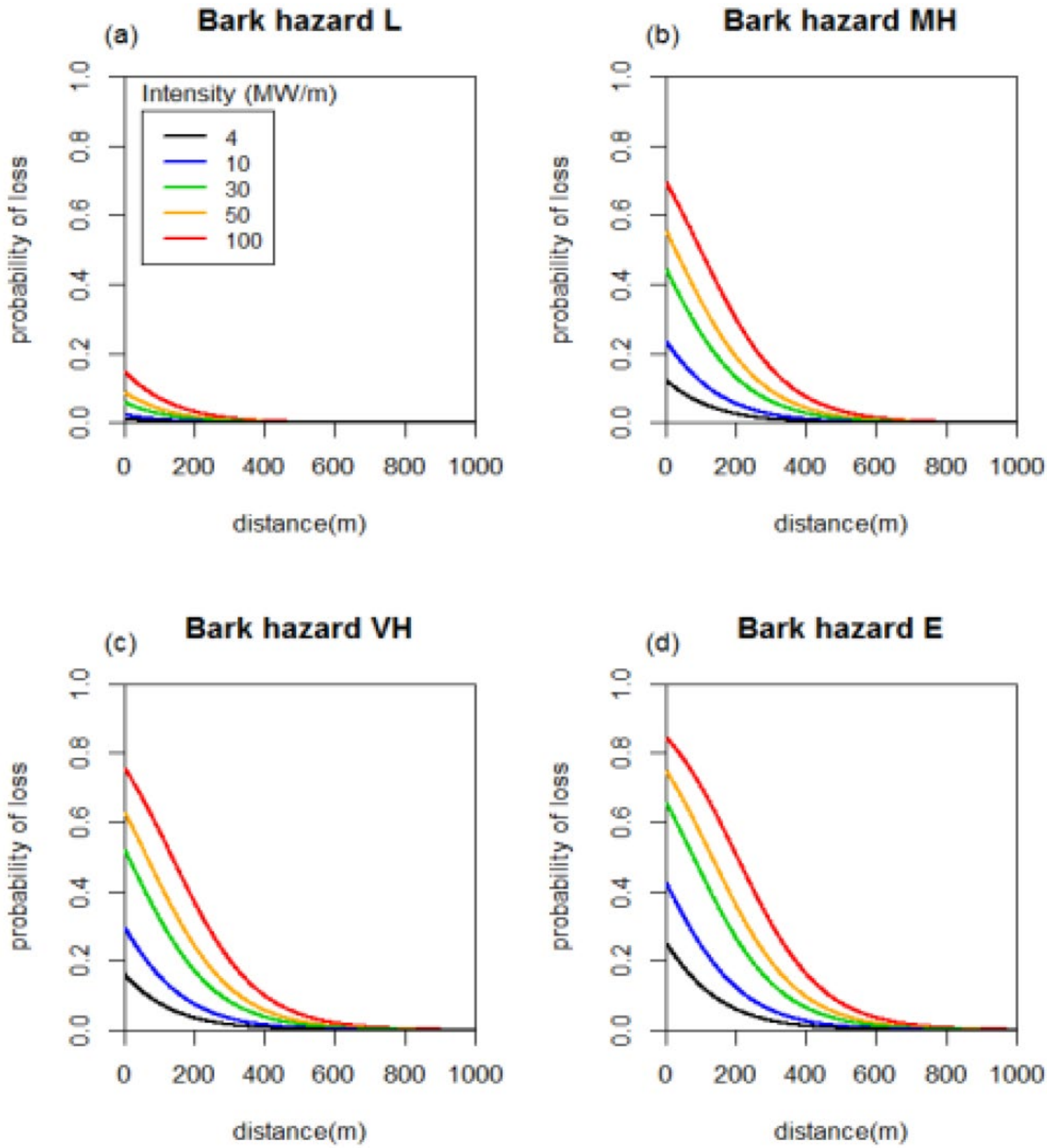
(iv) sensitivity analysis of critical aspects of a proposed design.

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

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

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

Appendix C. **Plots of Probability of Loss versus distance from forest for levels of fire intensity and at Low, Medium/High, Very High and Extreme Bark Hazard Levels from Kilinc [44]**



Appendix D. Event Trees Analysis of Single Dwellings

D1. Overview

An event tree analysis was undertaken as part of a study to inform decisions regarding Inputs and Acceptance Criteria for the National Construction Code Verification Method for Buildings in Bushfire Prone Areas[36] (refer Appendix B for a current draft of the Verification Method).

The event trees will form a useful benchmark and basis for the analysis of Class 9 buildings housing vulnerable occupants and some relevant content is included in this appendix

A series of event trees were constructed to assistance in the determination of an appropriate value for specification of the probability of survival of a building (prevention of fire initiation within a building) in the verification method.

Consolidated event trees are shown in Figure 22 through Figure 25 for the scenarios where the building occupants evacuate early and where they remain with the property and undertake active defense of the property for buildings with and without fire resistant construction.

D2. Consolidated Event Tree Inputs

The consolidated event tree inputs are presented in Table 23.

Table 23 Inputs for the Consolidated Event Trees Predicting House Survival Rates

Input Description	Probability
Design capable of achieving the design objective	0.8
Design correctly implemented / regulatory compliance	0.37
Building performance maintained in-use	0.40

The inputs were derived from event trees that are included in Figure 26 through Figure 28 so that the derivation is transparent. Further information on the derivation of the input probabilities for the event trees can be obtained from report EFT 2550-1.3 Inputs and Acceptance Criteria for the National Construction Code Verification Method for Buildings in Bushfire Prone Areas. England [36]

D3. Design capable of achieving the design objective

The probability of the design being capable of achieving the design objectives seeks to address limitations relating to design / methods of evaluation of materials / systems and material variability and a probability of satisfying the design objectives was estimated to be 0.8 in Figure 26. The following discussion explains the derivation of the estimated inputs to Figure 26:

The external envelope of a house and associated structure is intended to reduce the probability of fire initiation within a building when exposed to bushfire attack. The external envelope comprises a number of discrete elements that are connected together. Failure of any one element or the connection between elements can potentially lead to fire initiation within a building and subsequent loss.

The design / manufacturing process can be simplified to three broad processes

- Defining the exposure conditions
- Design of elements and interfaces to resist the defined exposure conditions
- Variations in material properties.

D3.1. Defining exposure conditions

AS 3959 calculates exposure conditions using models that incorporate a number of simplifying assumptions which are generally considered conservative to allow for the uncertainty but there will remain a small residual risk that the models could under predict exposure conditions. A probability of under-prediction due to modelling errors of 1% has therefore been assumed

D3.2. Design of elements and combinations of elements

The external façade of a building comprises a range of elements and interfaces including:

- Floors
- External Walls
- Windows
- Doors
- Roofs
- Eaves and facia details
- External structural members e.g. subfloor supports
- Decks
- Service penetrations (including pipes, air-conditioning units)
- Control joints / vents

If for each item, the design / selected system is the same there would be 10 elements and more than 10 different interfaces between elements. Failure of any one element or interface could compromise the performance of the building.

The probability of all members and interfaces achieving their design objectives (assuming they have the same probability of success can be calculated using the following relationship

$P_r = p^n$

Where:

P_r is the probability of all elements and interfaces achieving the design objective

p is the probability of the element or interface achieving its design objective (probability of success) and

n is the number of elements or interfaces (number of trials).

Under AS 3959 2009 elements of construction are specified as a result of the consensus view of a standards committee based on the available data and public comment or tests are performed under AS 1530.8.1. Both approaches have advantages and disadvantages but there will be a residual risk that the element will not resist the design exposure conditions. Even if the probability for an individual element or connection is low as demonstrated in Table 24

Table 24 Probability of failure during design of the building envelope based on probability of failure of individual elements and number of elements

Type of building	n (number of trials)	P (probability of success for building) for p values for individual elements or connection types			
		0.98	0.99	0.995	0.998
Simple	20	0.668	0.818	0.905	0.961
Complex	40	0.446	0.669	0.818	0.923

Based on Table 24 outcomes the proposed probability of 0.9 for the design stage appears reasonable.

D3.3. Material variations

The prescribed constructions are generic, and limits are not specified in relation to material properties. For tested prototypes a single test is required for classification purposes and therefore the sensitivity to variations in material properties may not be easily estimated under bushfire exposure conditions

The same principles used for the design of elements can be applied to material properties except that “n” would be based on the number of elements and joints rather than the number of different types of elements and joints.

For demonstration purposes “n” has been assumed to vary between 40 and 80 elements and connections in Table 25.

Table 25 Probability of failure due to material property variations of the building envelope based on probability of failure of individual elements and number of elements

Type of building	n (number of trials)	P (probability of success for building) for p values for individual component or connection types			
		0.98	0.99	0.995	0.998
Small building	40	0.446	0.669	0.818	0.923
Large Building	80	0.199	0.448	0.670	0.852

Based on Table 25 outcomes the proposed probability of 0.9 due to material property variations is considered a reasonable approximation.

D4. Design correctly implemented / regulatory compliance

Most of the inputs for the design correctly implemented / regulatory compliance tree were derived from the results of an audit undertaken by the Victorian Building Authority from late 2012 to mid-2014[52]. An audit was undertaken to measure the compliance of practitioners during the building permit process. The audit specifically focused on material the relevant building surveyor (RBS) receives, considers, records and submits to council. The scope of this audit was on documents contained in the building permit file and did not include the review of the physical building work.

The VBA also undertook an audit of the compliance of the external facades of approximately 170 high rise buildings in Melbourne based on inspections of buildings[53]. The probability of compliance was 0.49 but the event tree for bushfires includes the additional process of undertaking a BAL site assessment with a probability of compliance of 78%. If the external facade audit value is reduced accordingly (0.49 x 0.78) a value of 0.38 is obtained which is comparable with the value of 0.37 obtained from the event tree.

D5. Building performance maintained in-use

Data on the building and vegetation maintenance and building use that may compromise the bushfire resistance of a building was limited but anecdotally a relatively low probability would be expected based on observations of stored materials in close proximity or under buildings etc. A value of 0.4 was assumed.

D6. Consolidation of Design and Material Variation Results

The above results were combined to provide an estimate of the probability of the design objective being achieved yielding a value of 0.12. This is an extremely low value but from an examination of the event trees and comparison with audit results it is considered to be realistic. It was further validated against observations from the Black Saturday and Wye River Fires[36].

The control of building works and subsequent maintenance is addressed generally through State and Territory regulations and lies outside the scope of the technical provisions of the NCC and hence the verification method. This was discussed during a workshop with key stakeholders and it was determined for the verification method it was only necessary to specify the probability of a design being capable of achieving the design objective assuming correct construction and maintenance of the building and surrounding vegetation. However, when considering the potential effectiveness of regulating the construction of buildings, the probability of correct construction and maintenance of the building, adjacent buildings and vegetation should be taken into account.

The consolidated event trees also incorporate the potential for a building to withstand exposure to bushfire attack despite non-compliance with and without manual suppression.

The results are summarized in Table 26.

Table 26 Results from Event Tree Scenarios

Scenario	Probability of Building Survival
Bushfire-resistant construction and Manual suppression	0.65
Bushfire-resistant construction and no manual suppression and	0.29
Manual suppression and no bushfire-resistant construction	0.6
No manual suppression and no bushfire-resistant construction	0.2

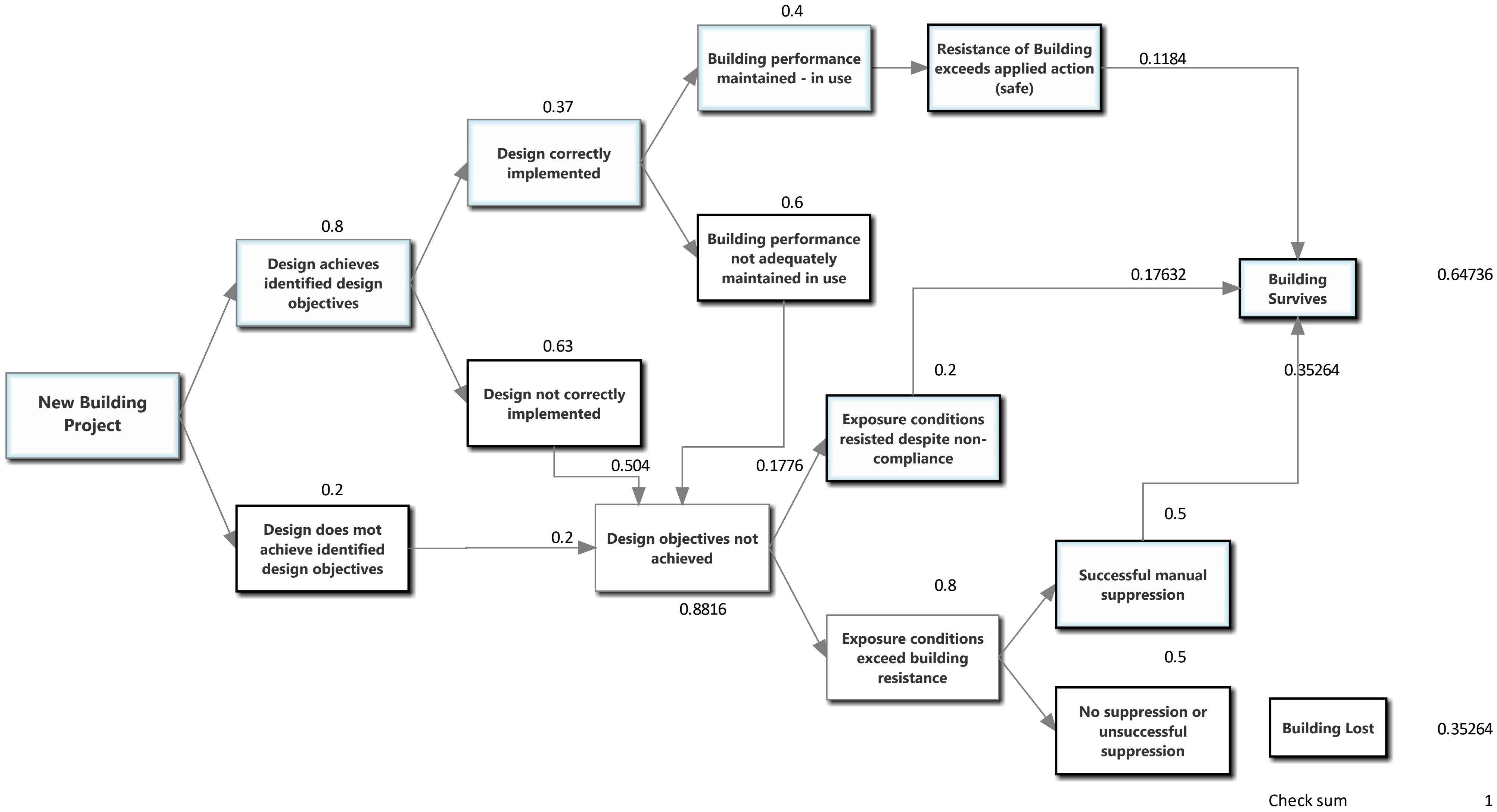


Figure 22 Consolidated Event Tree with manual suppression and bushfire resistant construction

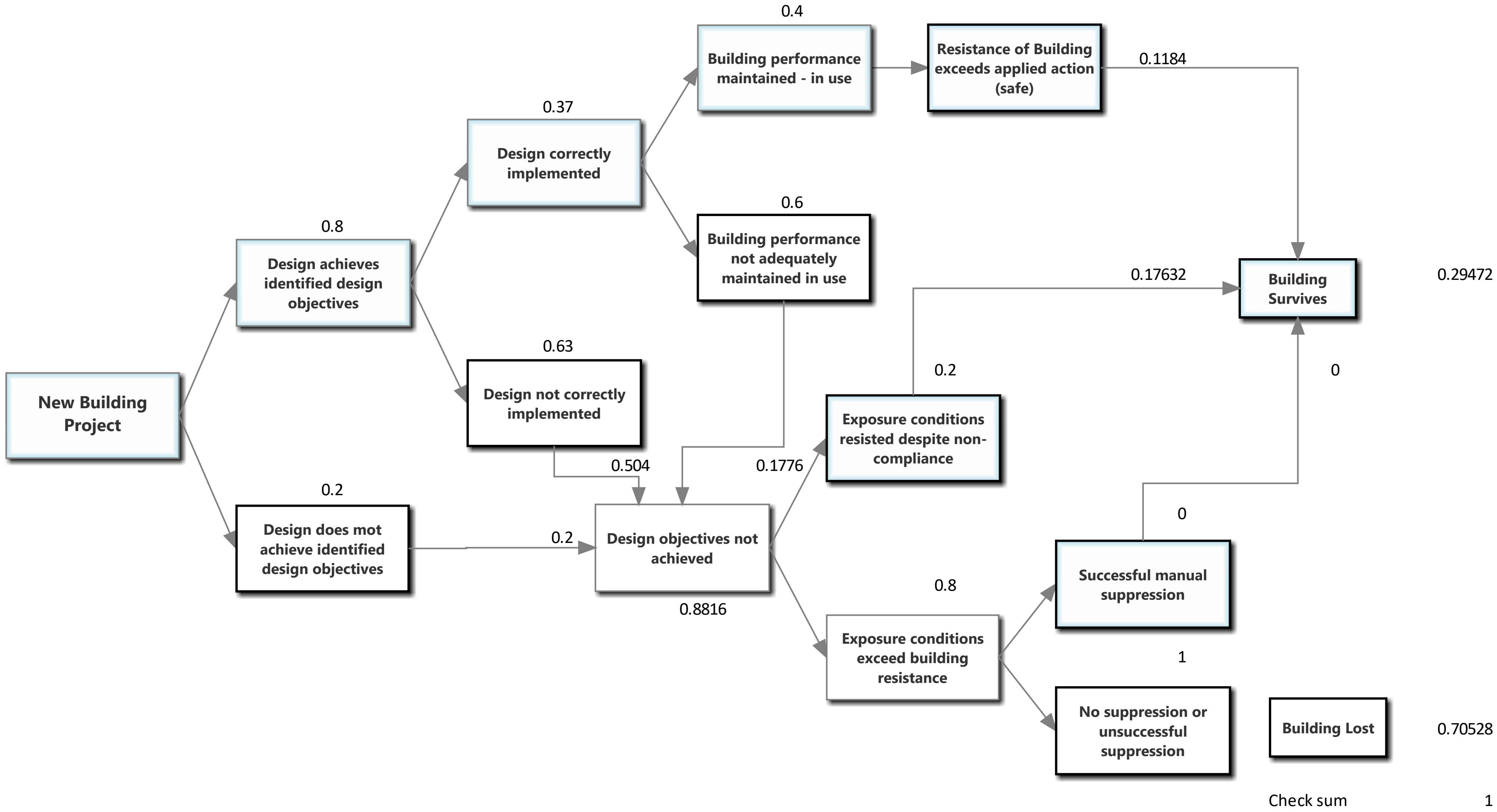


Figure 23 Consolidated Event Tree with bushfire resistant construction and no manual suppression

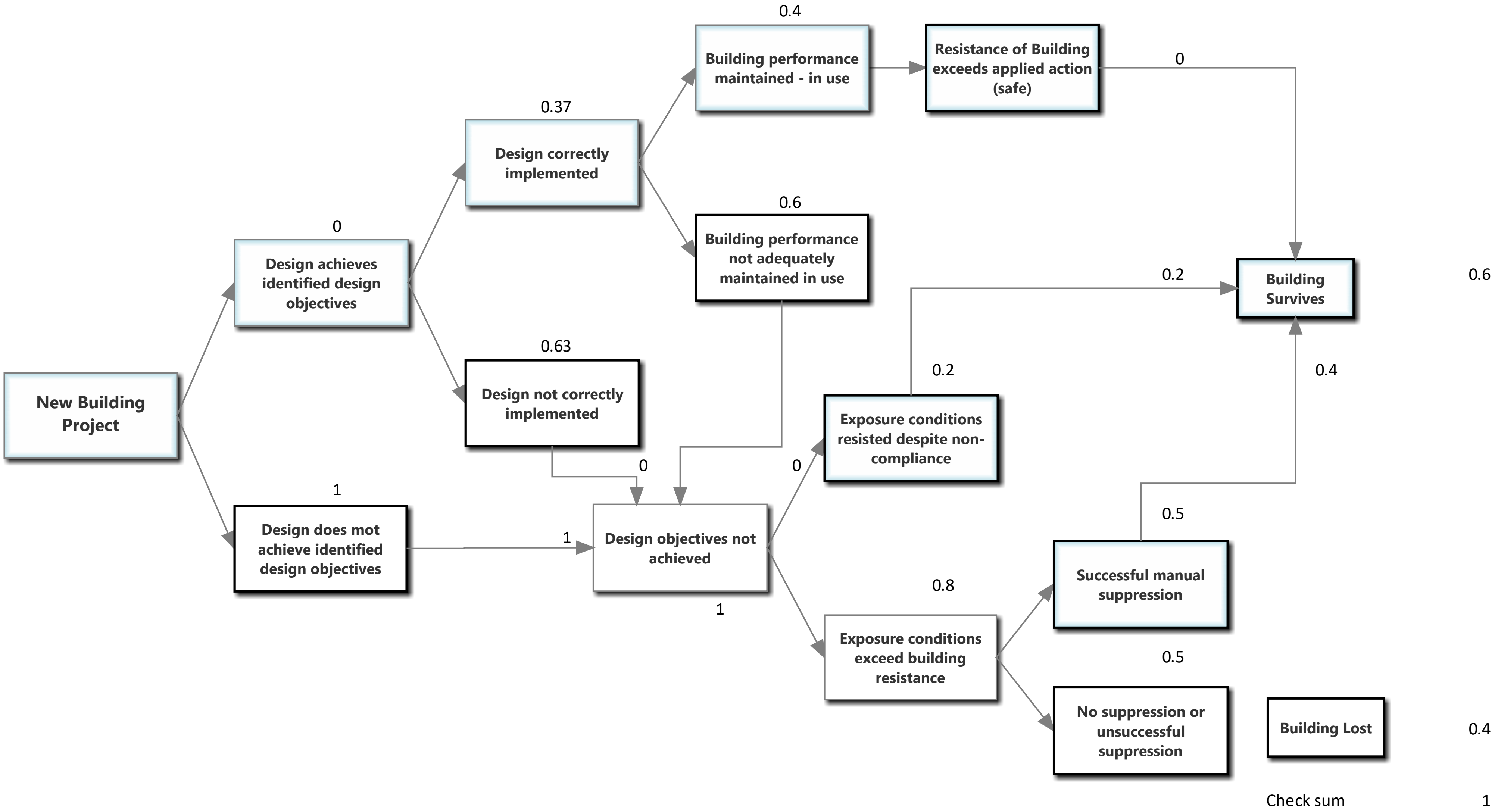


Figure 24 Consolidated event tree with manual suppression and no bushfire resistant construction

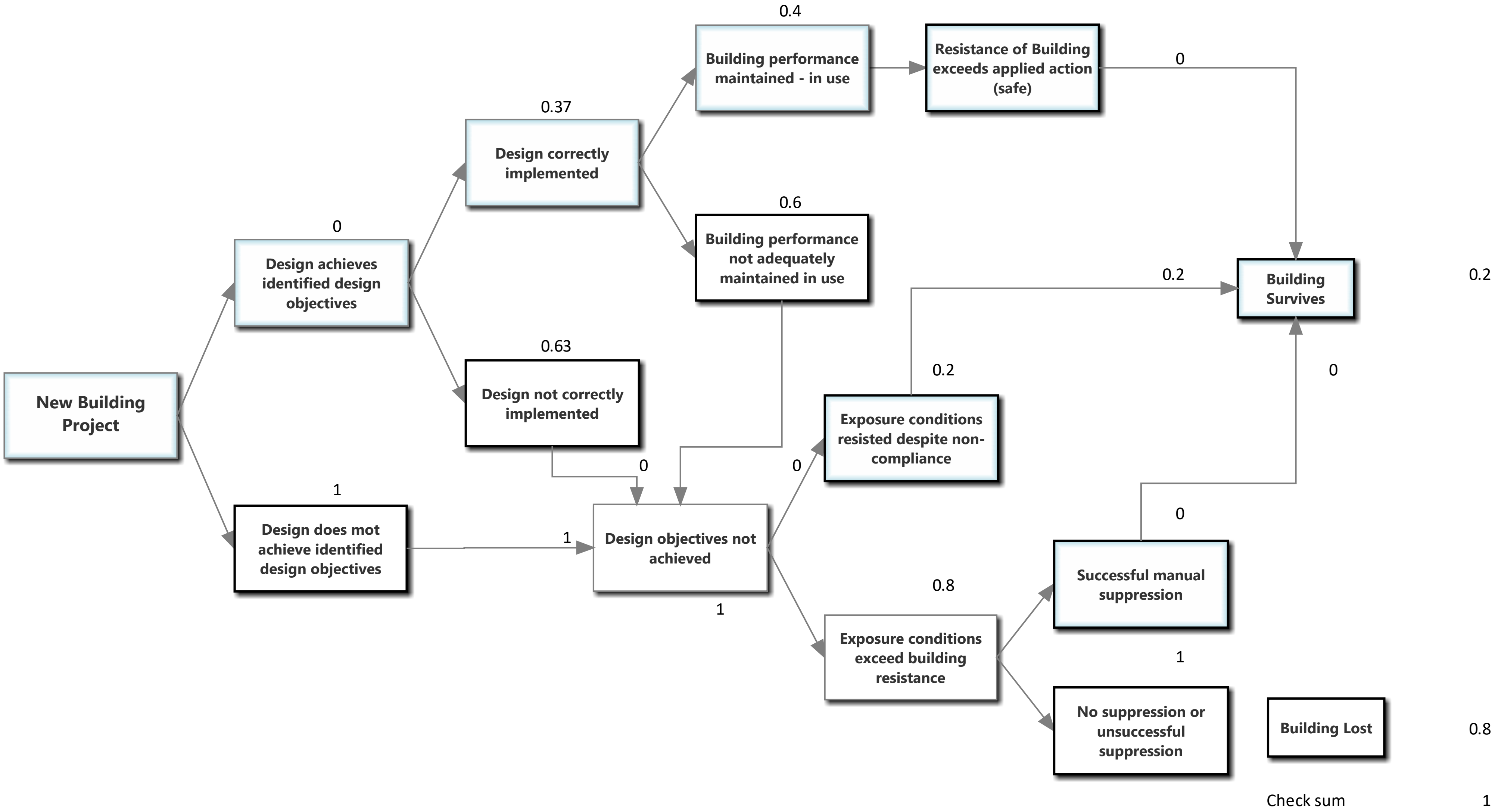


Figure 25 Consolidated event tree without manual suppression and no bushfire resistant construction

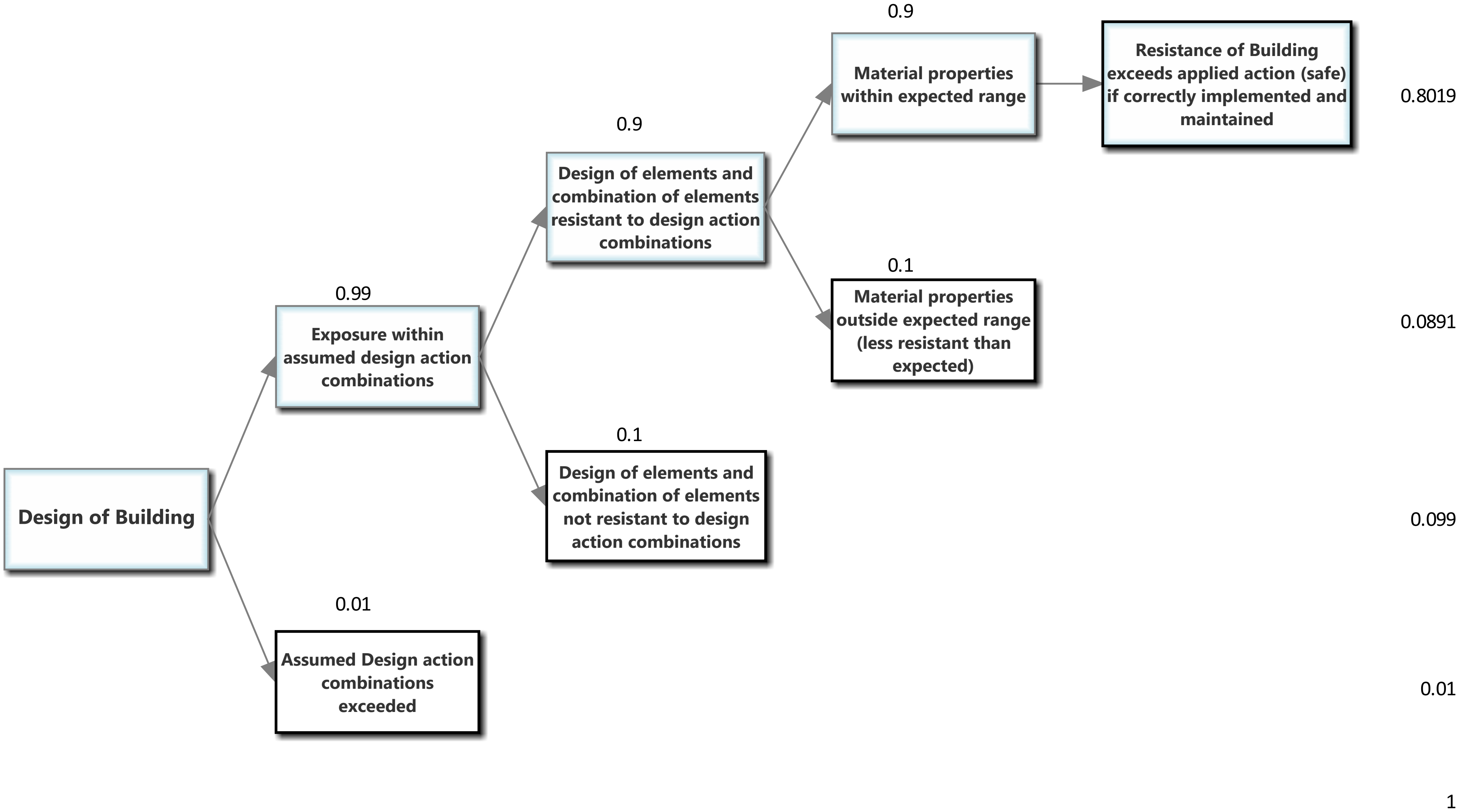


Figure 26 Event Tree for Design Process

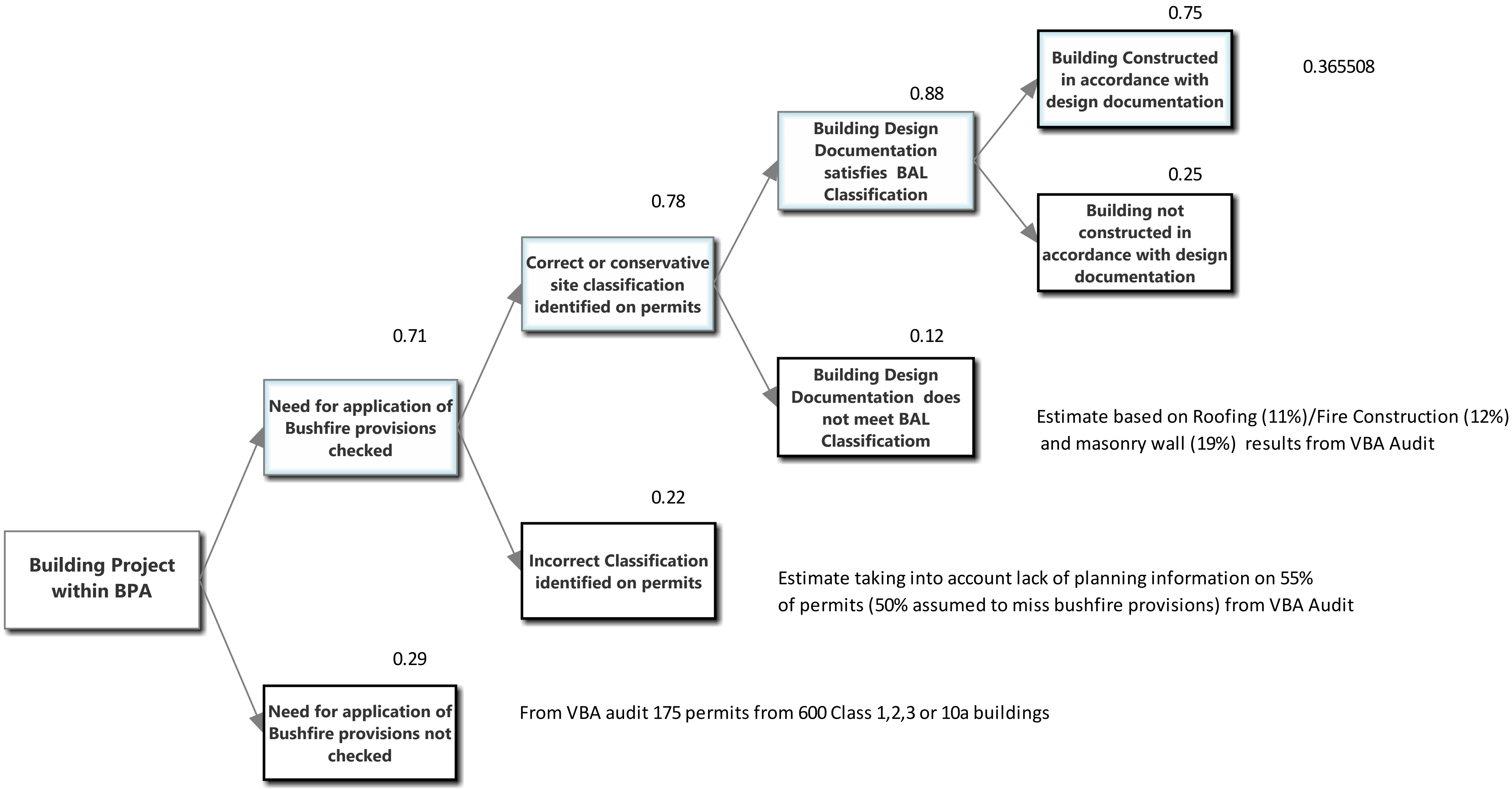


Figure 27 Event Tree for Administration of Regulation

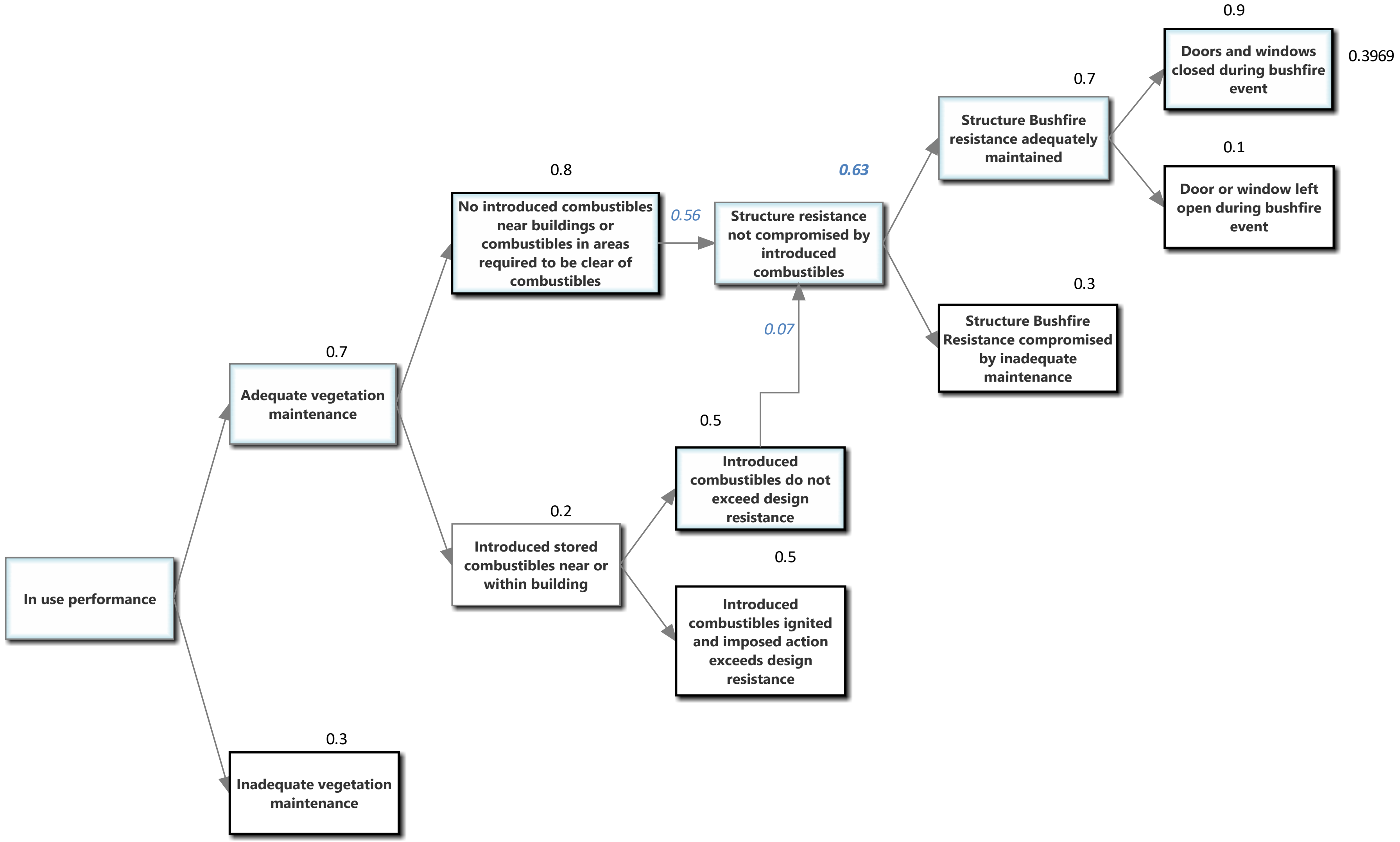


Figure 28 Event Tree For in-use performance of buildings

Appendix E. Event Trees for Class 9 Buildings Housing Vulnerable Occupants

The event trees from Appendix D were modified to take into account higher levels of compliance which are expected to be significantly higher for Class 9 buildings with greater oversight being provided during the design and operation of the facilities by health, education building and planning authorities within the State and Territory Administrations which include in some cases requirements for annual inspections and audits in addition to a potentially greater awareness of design teams and building operators as to the importance of and their responsibility for bushfire safety.

In addition, the proposed prescriptive requirements were derived with the intention of making the provisions less susceptible to non-compliances through the introduction of safety factors and redundancies in the design.

Provisions have also been included to facilitate fire brigade intervention to protect buildings housing vulnerable occupants and a high probability has been assigned to fire brigade intervention since it is expected that a high priority would be given to defending Class 9 buildings housing vulnerable occupants.

The resulting event trees are shown in Figure 29 through Figure 35 with text boxes indicating changes from the original event trees used for the evaluation of class 2 buildings. The outcomes of event trees shown in Figure 29 (adequacy of design), Figure 30 (correct implementation of design) and Figure 31 (maintenance-in-use) were input into the event trees shown by Figure 32 (no-suppression) and Figure 33 (manual suppression).

A summary of the expected risk of ignition within the building (loss of a building) for the Class 9 option compared to a Class 2 building is summarised in Table 27. The event trees given in Figure 34 and Figure 35 were developed to show the sensitivity of the outcomes to correct design implementation and maintenance but also the importance of manual fire suppression

Table 27 Proportion of Losses for proposed Class 9 building and Class 2 buildings from previous study based on AS 3959 requirements

Condition	Proportion of losses for Class 9 buildings	Proportion of losses for Class 2 buildings
No Suppression (See Figure 32)	10%	71%
Manual Suppression (See Figure 33)	1%	35%
No Suppression (full compliance at end of construction and maintained through building life) (See Figure 34)	1%	16%
Suppression (full compliance at end of construction and maintained through building life) (See Figure 35)	0.1%	8%

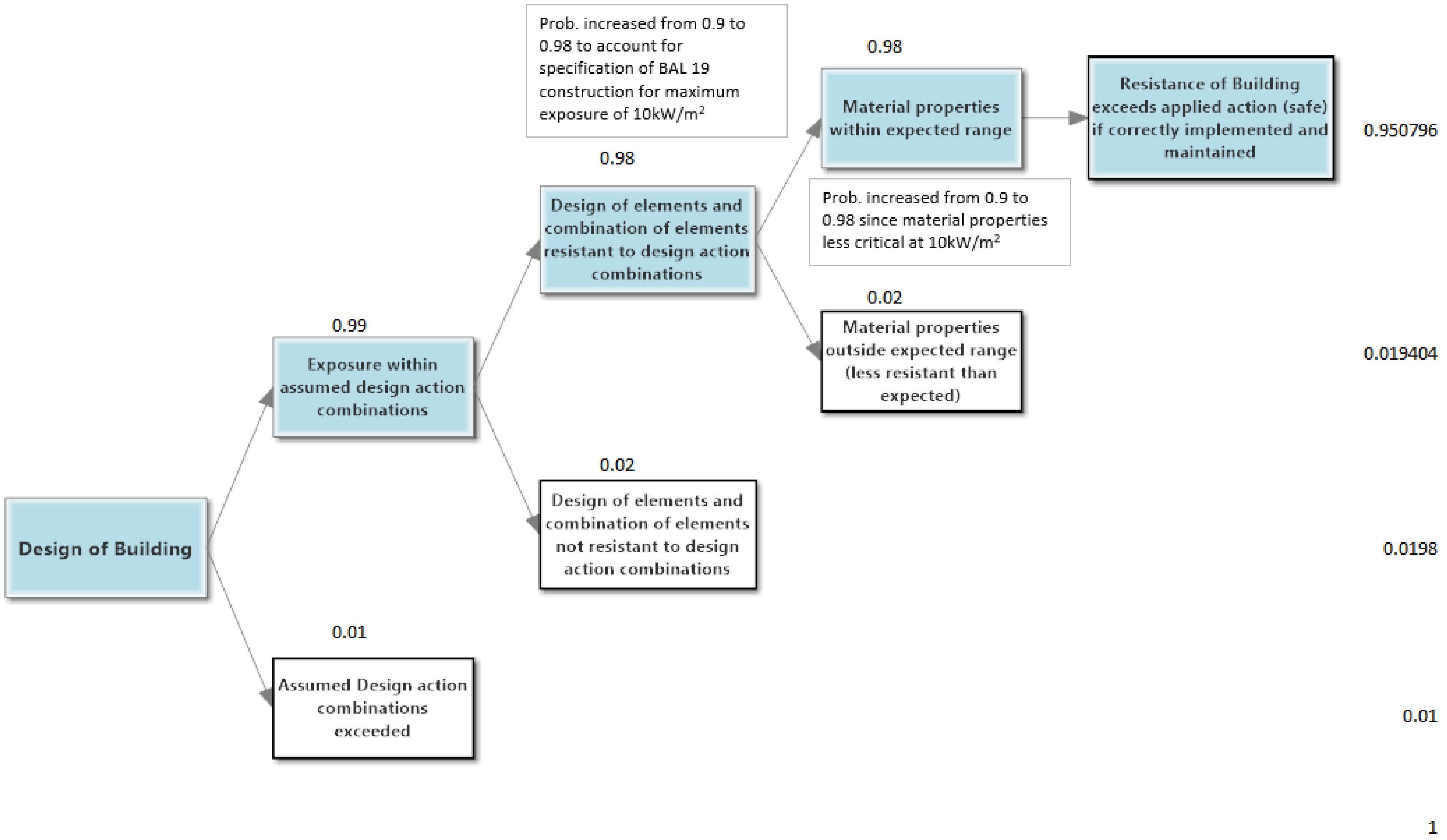


Figure 29 Event Tree for Design Process for Class 9 Buildings with explanation of change from values for Class 2 Buildings

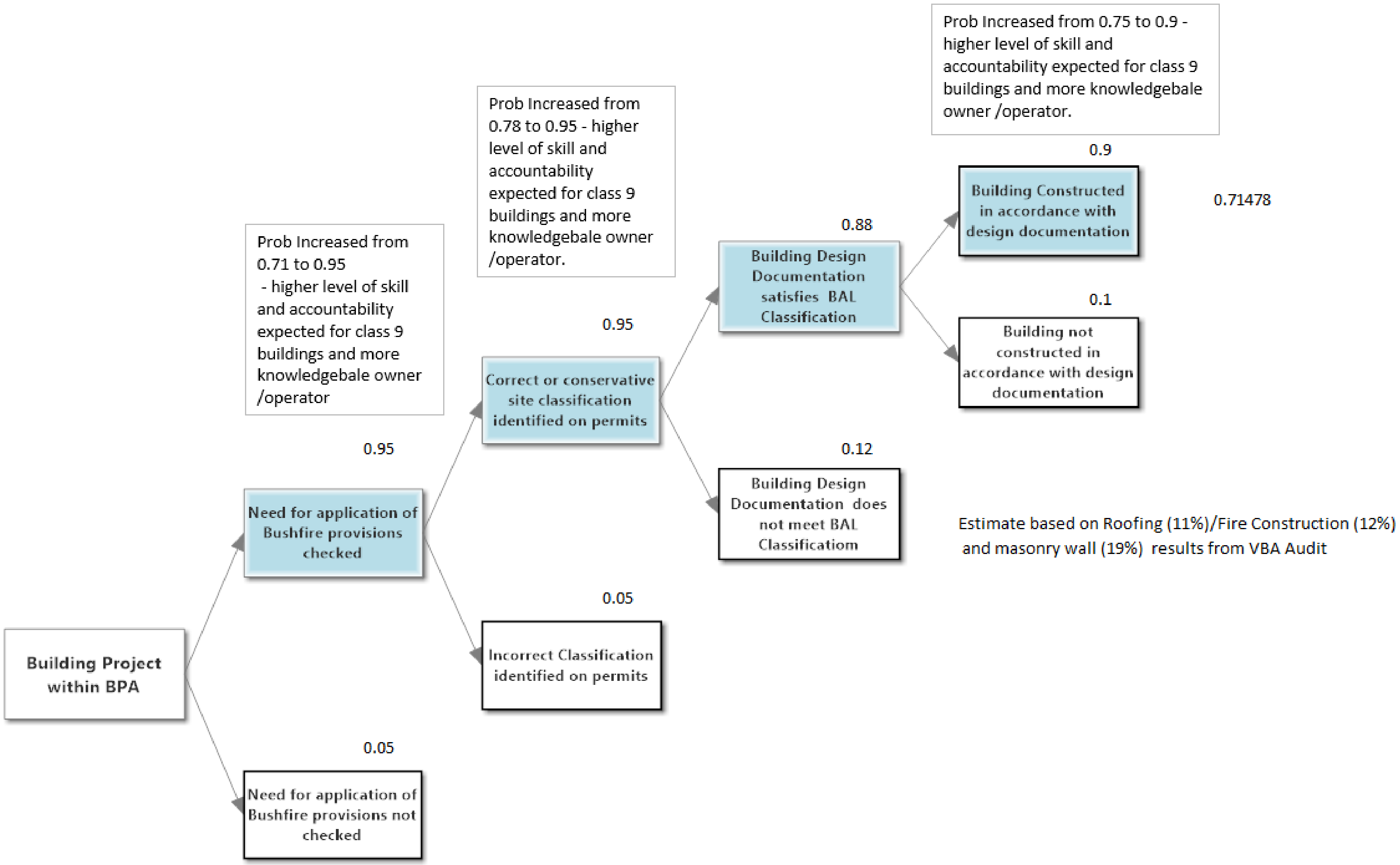


Figure 30 Event Tree for Regulatory Process for Class 9 Buildings with explanation of change from values for Class 2 Buildings

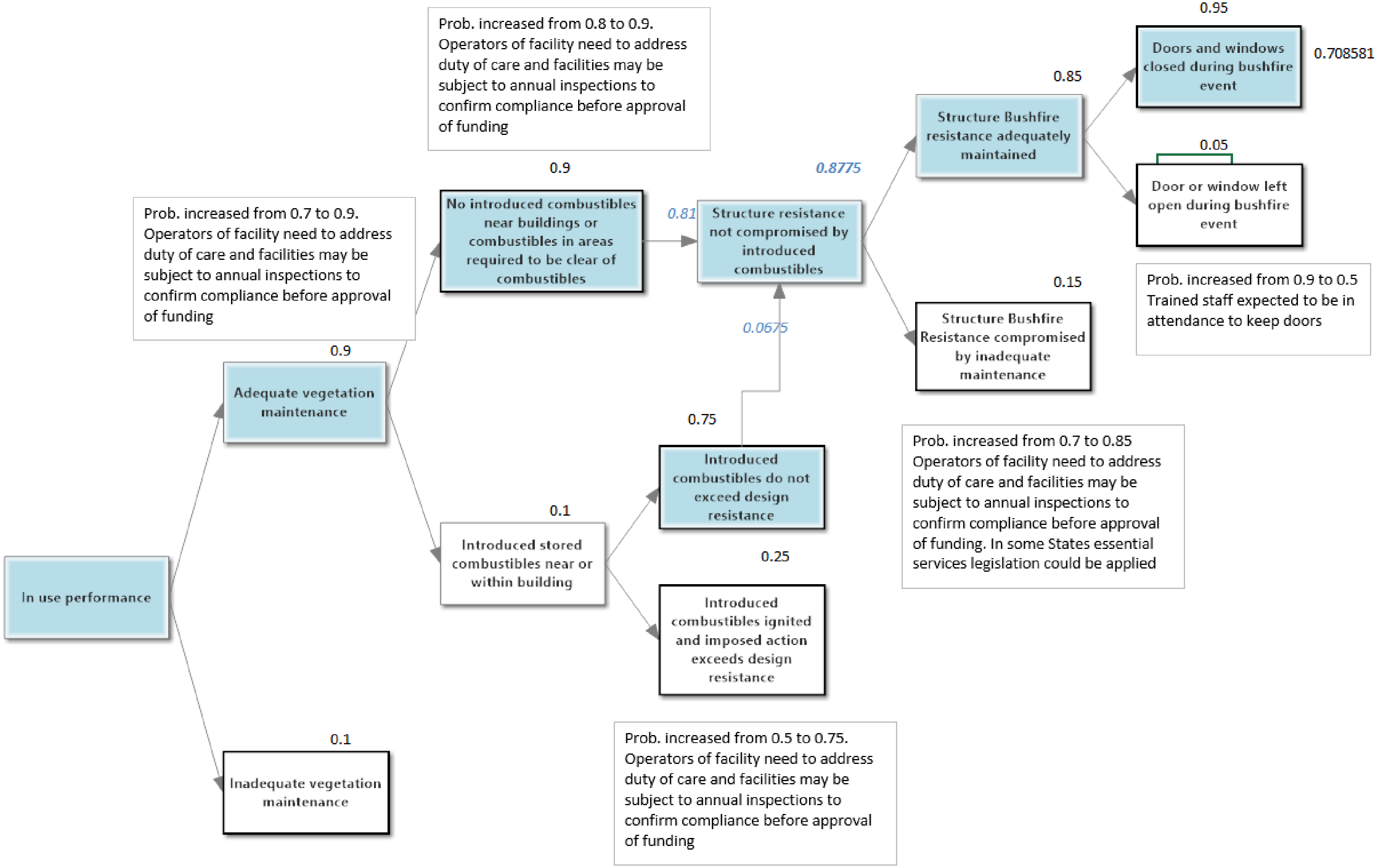


Figure 31 Event Tree for In-use Performance for Class 9 Buildings with explanation of change from values for Class 2 Buildings

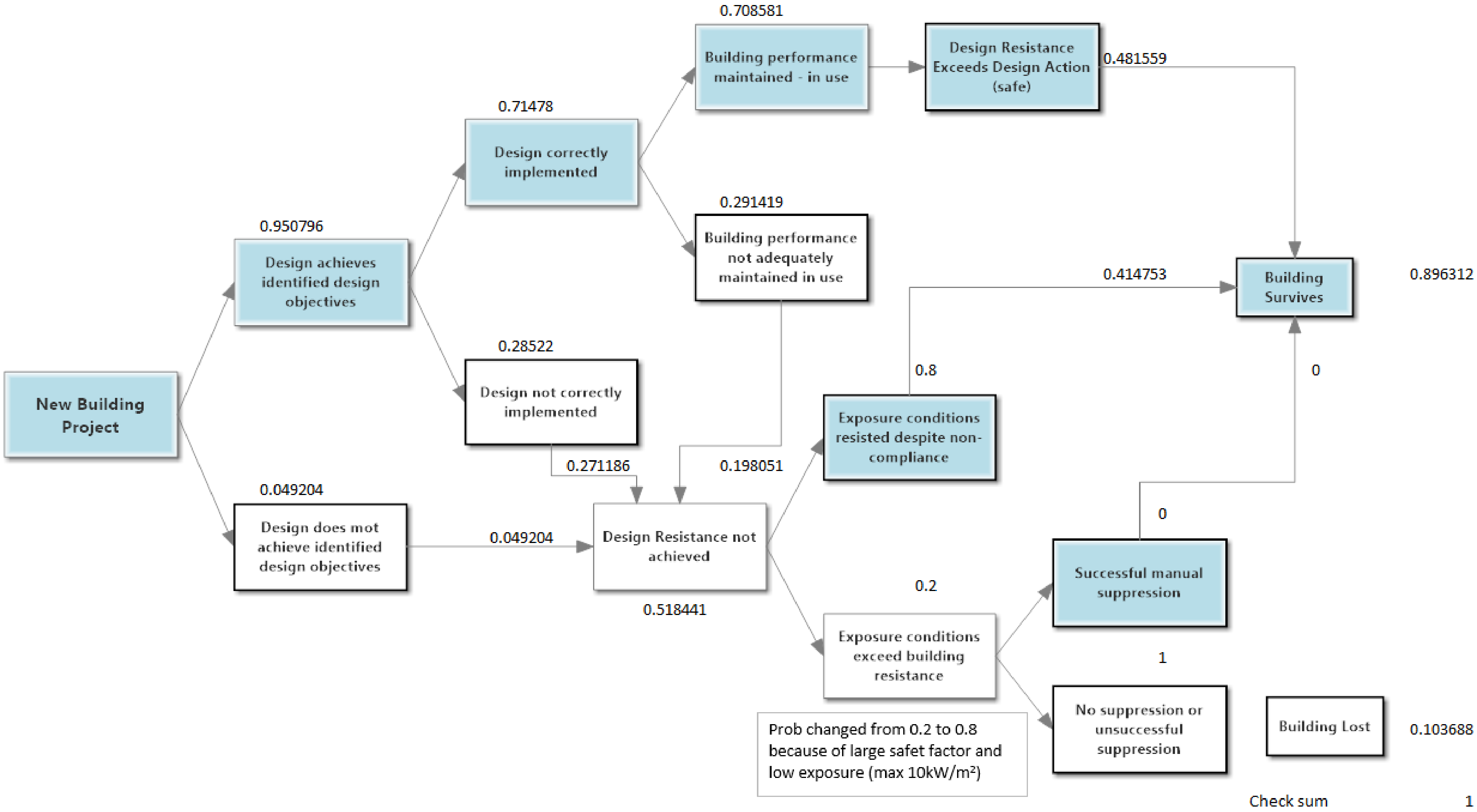


Figure 32 Consolidated Event Tree for Class 9 Buildings without Manual Suppression with explanation of change from values for Class 2 Buildings

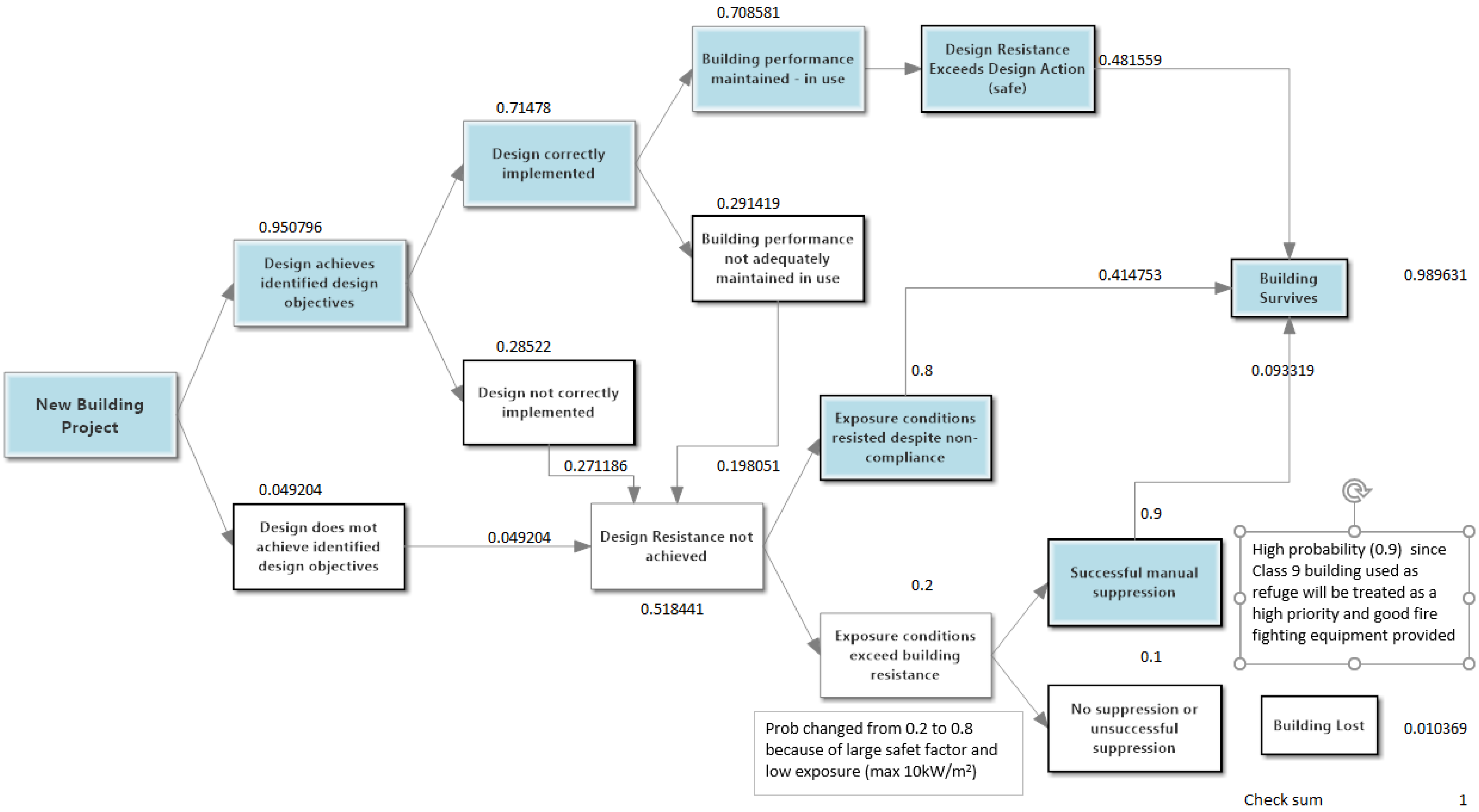


Figure 33 Consolidated Event Tree for Class 9 Buildings with Manual Suppression with explanation of change from values for Class 2 Buildings

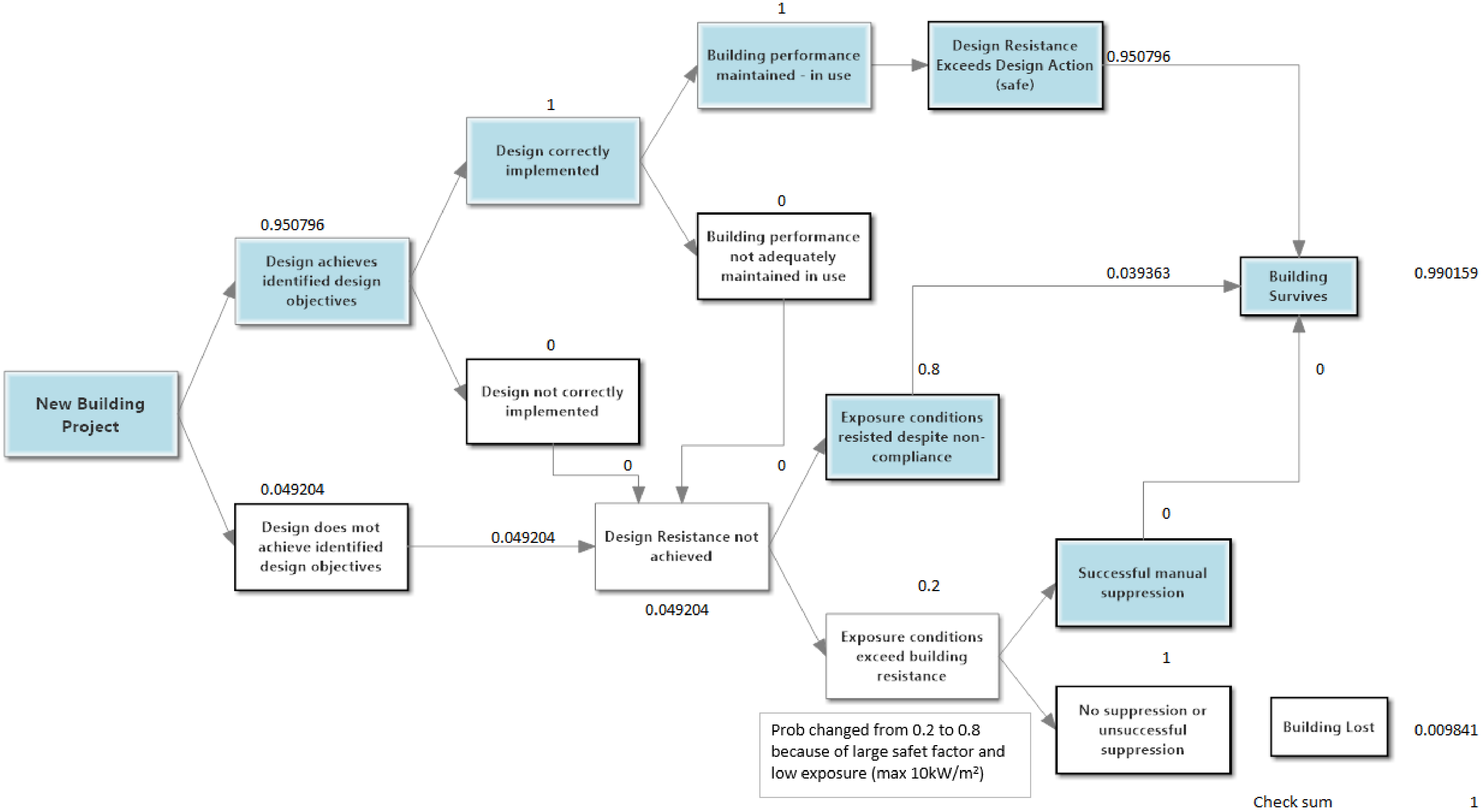


Figure 34 Consolidated Event Tree for Class 9 Buildings without Manual Suppression (Full compliance of Design Implementation and in use Performance)

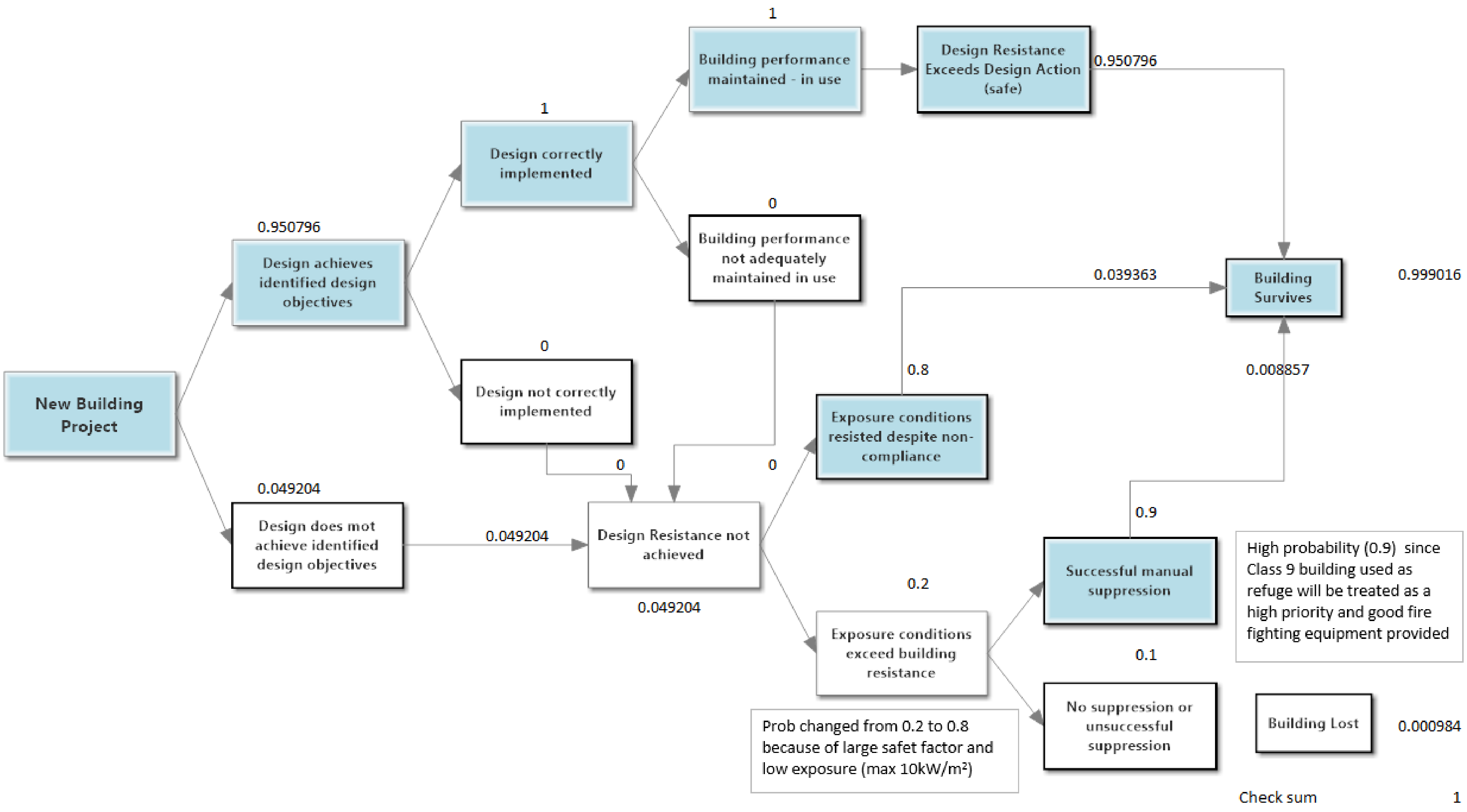


Figure 35 Consolidated Event Tree for Class 9 Buildings with Manual Suppression (Full compliance of Design Implementation and in use Performance)

Appendix F. **References**

1. ABCB, *National Construction Code 2016 Volume 1*, in *Building Code of Australia Class 2 to 9 Buildings*. 2016, Australian Building Codes Board: Canberra.
2. ABCB, *International Fire Engineering Guidelines Edition 2005*. 2005, Australian Building Codes Board: Canberra.
3. National_Fire_Protection_Association, *NFPA 550: Guide to the Fire Safety Concepts Tree*. 2012, National Fire Protection Association: Quincy, MA.
4. Standards_Australia, *AS 3959 Construction of Buildings in Bushfire-Prone Areas*. 2009, Standards_Australia: Sydney.
5. National_Bushfire_Warnings_Taskforce, *Australia"s revised arrangements for bushfire advice and alerts*. 2009, National Bushfire Warnings Taskforce under the auspices of the Australian Emergency Management Committee (AEMC).
6. ABCB, *National Construction Code 2016 Volume 1 Amendment 1*, in *Building Code of Australia Class 2 to 9 Buildings*. 2018, Australian Building Codes Board: Canberra.
7. ABCB, *National Construction Code 2019 -due for publication 2019.* 2019.
8. Standards_Australia, *AS 3959 Construction of Buildings in Bushfire-Prone Areas*. 2018, Standards_Australia: Sydney.
9. Standards_Australia, *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*. 2018: Sydney.
10. *Building Regulations 2016 (Tasmania)*. 2016: Australia.
11. *Director's Determination – Requirements for Building in Bushfire-Prone Areas*, B.C. (Tasmania), Editor. 2017: Tasmania.
12. *Bushfire-Prone Areas Code*. 2017: Tasmania.
13. *Building Regulations 2018 (Victoria)*. 2018: Australia.
14. Western_Australian_Planning_Commission, *State Planning Policy No. 3.7: Planning in Bushfire Prone Areas (SPP 3.7)*. Western_Australian_Planning_Commission, Editor. 2015, Western Australian Planning Commission: Western Australia.
15. Western_Australian_Planning_Commission, *Guidelines for Planning in Bushfire Prone Areas*, Western_Australian_Planning_Commission, Editor. 2017, Western Australian Planning Commission: Western Australia.
16. Productivity_Commission, *Reform of Building Regulation: Productivity Commission Research Report*. 2004, Canberra.
17. England, J.P., *Draft Bushfire Verification Method Handbook*. 2017.
18. Australian_Building_Codes_Board, *Design and Construction of Community Bushfire Refuges - Information Handbook*. 2014, Australian Government and States and Territories of Australia 2014: Canberra.
19. Department_of_Human_Services, *Capital Development Guideline — Series 7 Fire Risk Management Policy and Procedures - Engineering Guidelines*. 2013, Department of Human Services: Victoria.
20. Bennetts, I. and H.J. Van Ravenstein, *Fire Safety Management of Vulnerable Persons in Bushfire Prone Areas*, in *2nd ANZ Disaster & Emergency Management Forum*. 2018, Melbourne.
21. State_of_Victoria, D.o.H., *Residential aged care services bushfire ready resource*. 2010, State of Victoria, Department of Health: Victoria.
22. Department_of_Human_Services, *Capital Development Guideline — Series 7 Fire Risk Management Policy and Procedures - Hospitals*. 2013, Department of Human Services: Victoria.
23. SEMC, *Emergency Management Framework for Vulnerable People*. 2015, State Emergency Management Committee (SEMC).

24. Page, I. and D. Norman, *The Prevelance and Fire Safety Implications of Early Childhood Centres in Multi-Storey Buildings.*, in *New Zealand Fire Service Commission Research Report*. 2015, New Zealand Fire Service Commission and BRANZ: New Zealand.
25. Taciuc, A. and A.S. Dederichs, *Determining self-preservation capability in pre-school children*. 2014: Springer.
26. Teague, B., R. McLeod, and S. Pascoe, *Final report, 2009 Victorian bushfires royal commission Volume 1 Chapter 4*. 2010, Parliament of Victoria, Melbourne Victoria, Australia.
27. Blanchi R, et al., *Life and house loss database description and analysis -report to the Attorney-General's Department. CSIRO EP-129645*. 2012, CSIRO and Bushfire CRC.
28. Blong, R., D. Sinai, and C. Packham, *Natural perils in Australia and New Zealand*. 2000, Sydney: Swiss Reinsurance.
29. McAneney, J. and K. Chen, *The Bushfire Threat in Urban Areas.* Australasian Science, 2005. **26**(1).
30. ABS, *ABS 3105.0.65.001 Australian Historical Population Statistics, 2014*, A.B.o. Statistics, Editor. 2014: Canberra.
31. Crompton, R.P., et al., *Influence of location, population, and climate on building damage and fatalities due to Australian bushfire: 1925–2009.* Weather, Climate, Society, 2010. **2**(4): p. 300-310.
32. Honert, R.v.d., K. Haynes, and L. Coates, *Measuring the impacts of Bushfire on human fatalities and building losses*. 2014, Bushfire and Natural Hazards CRC: Hobart.
33. Blanchi, R., C. Lucas, and J. Leonard. *House Loss and weather conditions: An overview of weather condition during major bushfire that lead to house loss*. in *TASSIE FIRE*. 2007. Hobart: AFAC/Bushfire CRC.
34. Chen, K. and J. McAneney, *Bushfire Penetration into Urban Areas in Australia: A Spatial Analysis. Report for the Bushfire CRC*. 2010.
35. Blanchi, R., et al., *Meteorological conditions and wildfire-related houseloss in Australia.* International Journal of Wildland Fire, 2010. **19**(7): p. 914-926.
36. England, J.P., *EFT 2550-1.3 Inputs and Acceptance Criteria for the National Construction Code Verification Method for Buildings in Bushfire Prone Areas*. 2016, EFT Consulting: Melbourne.
37. Chen, K., *Counting bushfire-prone addresses in the greater Sydney region.* Planning for Natural Hazards, 2005.
38. Dowdy, A.J., et al., *Australian fire weather as represented by the McArthur forest fire danger index and the Canadian forest fire weather index*. 2009, Centre for Australian Weather Climate Research,: Melbourne, Australia,.
39. Marquez, M.C. and L. Marquez, *Bushfire risk mitigation program by Victoria's Department of Education and Training.* International Journal of Decision Sciences, Risk and Management, 2015. **6**(2): p. 169-186.
40. Standards_Australia, *AS 5414-2012 Bushfire water spray systems*. 2012, SAI Global: Sydney.
41. Ramsay, G.C., N.A. McArthur, and V. Dowling. *Building in a fire-prone environment: Research on building survival in two major bushfires*. in *Proceedings Linnean Society of New South Wales*. 1996. Linnean Society of New South Wales.
42. Bushfire_CRC, *Victorian 2009 bushfire research response: Final Report*. 2009, Bushfire CRC.
43. State-_of_Victoria, D.o.H., *Relocation, shelter in place and evacuation - Guidance note for public and private health services, hospitals and residential aged care services*. 2013, State of Victoria, Department of Health: Victoria.
44. Kilinc, M., W. Anderson, and D. Anderson, *A Statistical Analysis of Bushfire Penetration into Peri-urban areas*. 2014, Bushfire and Natural Hazard CRC: Melbourne.
45. Douglas, G., et al., *Use of the Extreme Value Analysis in Determining Annual Probability of Exceedance for Bushfire Protection Design.* Fire Safety Science, 2014. **11**: p. 1379-1392.
46. Douglas, G., et al. *The Role of Extreme Value Analysis to enhance defendable space for construction practice and planning in Bushfire Prone Environments. .* in *Bushfire and*

Natural Hazards CRC and AFAC Conference. 2015. Adelaide: Bushfire and Natural Hazards CRC.
47. Douglas, G., *Challenges in developing a Bushfire Verification Method*, in *Fire Australia 2016*. 2016, Fire Protection Association of Australia: Victoria.
48. Douglas, G., *Property Protection from Extreme Bushfire Events under the Influence of Climate Change*. 2017, Western Sydney University.
49. Hines, F., *Overall fuel hazard assessment guide*. 2010: Victorian Government, Department of Sustainability and Environment.
50. Bowditch, P., *House fire spread, an investigation-Gulgong NSW*. 2006, Bushfire CRC.
51. Standards_Australia, *AS 1530.8.1-2007 Methods for fire tests on building materials, components and structures - Tests on elements of construction for buildings exposed to simulated bushfire attack - Radiant heat and small flaming sources*. 2007: Sydney.
52. Victorian_Building_Authority, *Building Permit Audit - Findings and Actions - Industry Report*. 2014, Victorian Building Authority: Melbourne.
53. Victorian_Building_Authority, *External Wall Cladding Audit Report*. 2016, Victorian Building Authority: Melbourne.