WOOD & GRIEVE ENGINEERS

Bay 4 & 5, 1-3 Hickson Rd, The Rocks

Fire Engineering Report

Prepared for:

Place Management NSW

Prepared by:

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Project No. 33307-2

Date:
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Revision

REVISION	DATE	COMMENT	APPROVED BY
01	23/04/18	Draft – Issued for Comment	
02	28/05/18	Final FER to address FRNSW and other stakeholder comments	LW

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Executive Summary

This document is a Fire Engineering Report (FER) for Bay 4 and 5 of the existing heritage building located at 1-3 Hickson Road, The Rocks NSW 2000. This building comprises 5 compartments (Bays 1-5).

As per the Building Code of Australia (BCA) 2016[1], the proposed development is classified as Class 5 and Class 9b with a rise in storeys of 5 and an effective height of < 25 m.

The proposed Performance Solutions for this development are listed in the table below with the applicable BCA Deemed-to-Satisfy (DtS) Provisions, relevant BCA Performance Requirements and the proposed methods of assessment.

All other items of fire and life safety which have not been identified in Table 1 are to be in accordance with the BCA DtS provisions. Any change in this information to suit future building works or re-organisation will require further analysis to confirm compliance with the regulations and the fire engineering assessment.

The fire safety strategy outlined in this report has been developed to provide a practical fire safety design for the scheme, taking into account the various design constraints incumbent on the design by virtue of its site, whilst ensuring a robust fire safety philosophy for both building occupants and the Fire Brigade.

Table 1 : Summary of Performance Solutions

No.	Description of Performance Solution	BCA Clause	Performance Requirements	Assessment Method
1	Fire hazard properties associated with the timber floor / ceiling construction do not satisfy Specification C1.10 of the BCA.	C1.10, Spec. C1.10	CP4	A0.5(b)(ii)
2	Classifications between storeys results in class 5 & Class 9b uses that are not fire separated between storeys - Bay 2-4.	C2.9	CP2	A0.5(b)(ii)
	Requirements of C3.12 are not able to be satisfied due to the absence of fire rated construction associated with the floor construction between storeys.	C3.12	CP8	A0.5(b)(ii)
	Existing and proposed buildings elements such as floors, beams and columns do not achieve the required fire resistance level of construction.	Spec. C1.1	CP1, CP2, CP4	A0.5(b)(ii)
	The floors and supporting structural elements do not satisfy Clause 2.2 of Specification C1.1.	Clause 2.2 of Spec. C1.1	CP1, CP2	A0.5(b)(ii)
	Services riser shafts do not achieve an FRL due to reliance on timber floor construction for support.	Spec. C1.1	CP1, CP2	A0.5(b)(ii)
	The exposed steel plates joining an existing concrete beam to a new concrete beam means that the floor it supports is unlikely to achieve the required FRL.	Spec. C1.1	CP1, CP2	A0.5(b)(ii)
3	Existing fire pump room within Bay 2 is not fire separated from the remainder of the building.	C2.12	CP2, CP6	A0.5(b)(ii)

Executive Summary

No.	Description of Performance Solution	BCA Clause	Performance Requirements	Assessment Method
4	Fire stair No 1 discharges to within the confines of the building contrary to the requirements of D1.7(b).	D1.7(b)	DP4, DP5	A0.5(b)(ii)
	Stair 2 & 5 incorporates rising and descending flights contrary to the requirements of Clause D2.4 of the BCA.	D2.4	DP5	A0.5(b)(ii)
5	Hydrant and sprinkler systems to share water supply infrastructure (single town main and 2 pumps) compliant with AS2118.6. Downstream of the pumps the manifold pipework will supply the Sprinkler system and the Hydrant system separately.	E1.3, AS2419.1, AS2118.6	EP1.3	A0.5(d)
6	Fire hose reels are proposed to be omitted from Bay 1.	E1.4, AS2441	EP1.1	A0.5(d)
7	Access to the fire pump room is not fire-isolated.	E1.3, AS2419.1	CP2, EP1.3, EP2.2	A0.5(b)(ii)
	The hydrant and sprinkler booster is not protected in accordance with AS2419.1.	E1.3, AS2419.1	CP2, E1.3	A0.5(b)(ii)

1. Introduction

1.1 Scope

WGE has been engaged to develop a performance based fire safety strategy for Bay 4 and 5 of the existing heritage listed building located at 1-3 Hickson Road, The Rocks NSW 2000. The fire safety objective of this strategy is limited to achieving compliance with the Performance Requirements of the Building Code of Australia (BCA 2016) [1]. Fundamentally the BCA aims to protect life safety, prevent fire spread to adjacent buildings, and facilitate Fire Brigade operations.

Our approach to Fire Engineering is in accordance with the International Fire Engineering Guidelines (IFEG) [2]. WGE adopt worldwide best practice and standards as outlined in Section 0.1.1 (of the IFEG), and using the document as general guidance on the analysis process without strictly following each individual sub-system as per Section 1.3 of the IFEG, which permits different approaches to demonstrate compliance. In this light guidance documentation such as the New Zealand Verification Method 2 [3] and C/AS2 – C/AS7 Acceptable Solutions for Buildings [4], British Standard PD 7974 Series [5], Society of Fire Protection Engineering Handbook of Fire Protection Engineering [6], CIBSE guide E [7] and the NFPA Series [8] are all referenced.

1.2 Design team and stakeholders

The relevant project stakeholders are listed in Table 2.

Table 2 : Design team and stakeholders information

Role	Organisation / Company	Person
Client / Developer	Place Management NSW Ltd	Victoria Daniels
Project Manager	The Project Studio	Glenn Johnson
Architects	TKD Architects	Jocelyn Jackson
Building Surveyors	Environet Consultancy	Peter Rossello
Fire Brigade Representative	FRNSW	Duke Ismael

1.3 Relevant Documentation

The relevant documents and drawings reviewed and assessed as part of this report are listed in Table 3.

Table 3 : Document Register

Document Name/Description	Organisation	Date	Revision
BCA Report	Environet Consultancy	29/11/17	2
Architectural Drawings	TKD Architects	26/02/18	B

1.4 Report application and assumptions

Please note all referenced documentation, standards and texts are done so in the following style “[ ]”. Appendix A 1.1, details the full references made mention of within this report.

It should be noted that the figures presented in the Performance Solutions provide an indicative supporting mark-up of the identified non-compliances. The figures are used for illustrative purposes only and should be read in conjunction with the drawings prepared by the architect or engineers for this project.

The following assumptions will be incorporated into the Fire Engineering Analysis:

- Only one fire will occur at a time within the development.
- All exit routes are maintained clear of obstructions.
- The analysis is limited to the assessment of single / accidental fires as intended by the BCA. The fire scenarios investigated within this document may be representative of intentional fires caused by an opportunistic arsonist; however multiple fires, severe acts of malice intent, terrorism, sabotage, or by wilful interference with fire and life safety systems are considered outside the scope of this assessment.
- No property protection requirements have been advised and therefore included within the design. Some property protection is inherent within the life safety measures required for the building however this is incidental.
- We have not been advised of any insurers’ requirements and therefore this has not been considered within the design.
- All essential services, equipment services and strategies will be maintained to the operational capacity to which they were designed, and will correctly function during a fire situation.
- All other components of the building not addressed within this document will be installed to the requirements of the Deemed-to-Satisfy provisions of the Building Code of Australia applicable at the time of design.
- The Fire Engineering Assessment carried out is specific to this project. The findings and outcomes of this document shall not be used outside the scope of this project.

2. Building and Occupant Characteristics

2.1 Building Characteristics

2.1.1 Building Location

The existing building is located at 1-3 Hickson Road, The Rocks NSW 2000 as shown in Figure 1. This building consists of five (5) main compartments, Bay 1 to Bay 5. Each level of Bay 4 and 5 will have access to at least two (2) exits.

The proposed development is classified as heritage and will be used as an office (class 5) and education (9b) space.

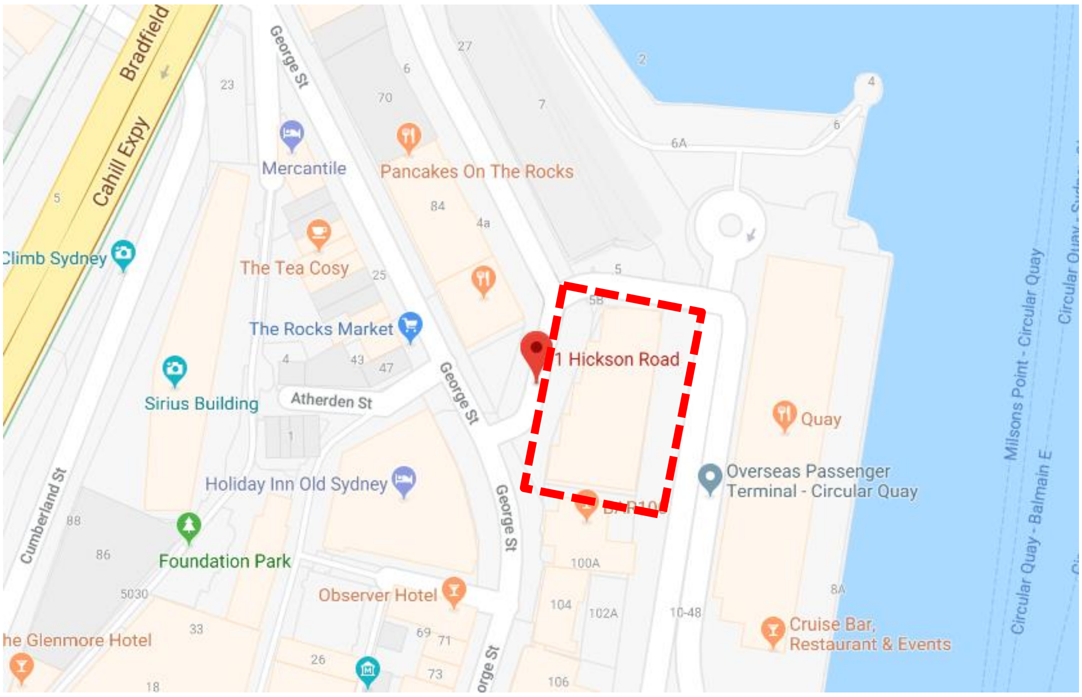


Figure 1 : Building Location

2.1.2 Building Classification

The Building Classification has been tabulated in Table 4, based on the information provided in the BCA Design Assessment Report.

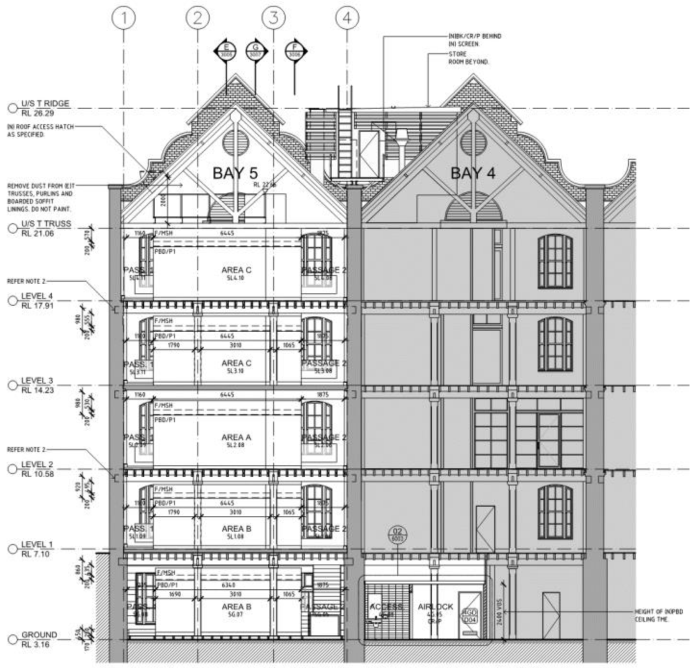
Table 4 : Building BCA Classification

BCA Clause / Section	Description	Description or requirements
A1.1	Effective height	< 25 m
A3.2	Building occupancy & BCA Classification	Class 5 (office space), Class 9b (education)
C1.1	Construction type	Type A construction required
C1.2	Rise in Storeys	5
Table C2.2	Fire compartment floor area and volume	< 8000 m^2 & < 45,000 m^3

Building and Occupant Characteristics

2.1.3 Building Description, Occupant Loading and Evacuation

The subject building is existing and is of heritage significance. As a result, the building contains exposed timber floor / ceiling structures, however the building has been voluntarily sprinkler protected to address some of the deficiencies associated with old heritage buildings. The building consists of 5 Bays.



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2.2 Occupant Characteristics

The characteristics of occupants and their corresponding interaction with the building environment, staff, queues and people around them is important when trying to understand the evacuation process. It is therefore necessary to consider the characteristics of the occupants that can be expected in the building when undertaking Fire Engineering Analysis, as highlighted in the IFEG [2].

The principal occupant characteristics for the building are listed in Table 5, using Table 2 of BS 9999 [7].

Table 5 : Occupant Characteristics

Occupants	Description	Characteristics
Staff	Maintenance, security & building employees	Awake and familiar
Students	Students attending the school portion of the building	Awake and unfamiliar
Others	Visitors	Awake and unfamiliar

Occupants within this building will consist partly of employees, who are expected to have received specific emergency training. As such, they are assumed to be aware of the emergency procedures in place at this facility, as well as the location of all exits and fire-fighting equipment.

The building will also contain a significant number of students who may or may not be familiar with the layout of the building or the location of all exits. However, students should be able to navigate to the exits easily due to guidance given by the teaching staff or exit signage provided throughout the building. They are also expected to be awake when inside the building.

All visitors are assumed to be accompanied by the building employees at all times when the building is lawfully occupied. Accordingly, they should be able to navigate to the exits easily due to guidance given by the employees and exit signage provided throughout the building.

3. Fire Brigade Intervention

3.1.1 Location of local Fire Station and building access

The site is located approximately 1.1 km (as determined by Google Maps) from The Rocks' Fire Station, 166 Kent St, The Rocks NSW 2000 as depicted in Figure 2. Pyrmont Fire Station is also in close proximity.

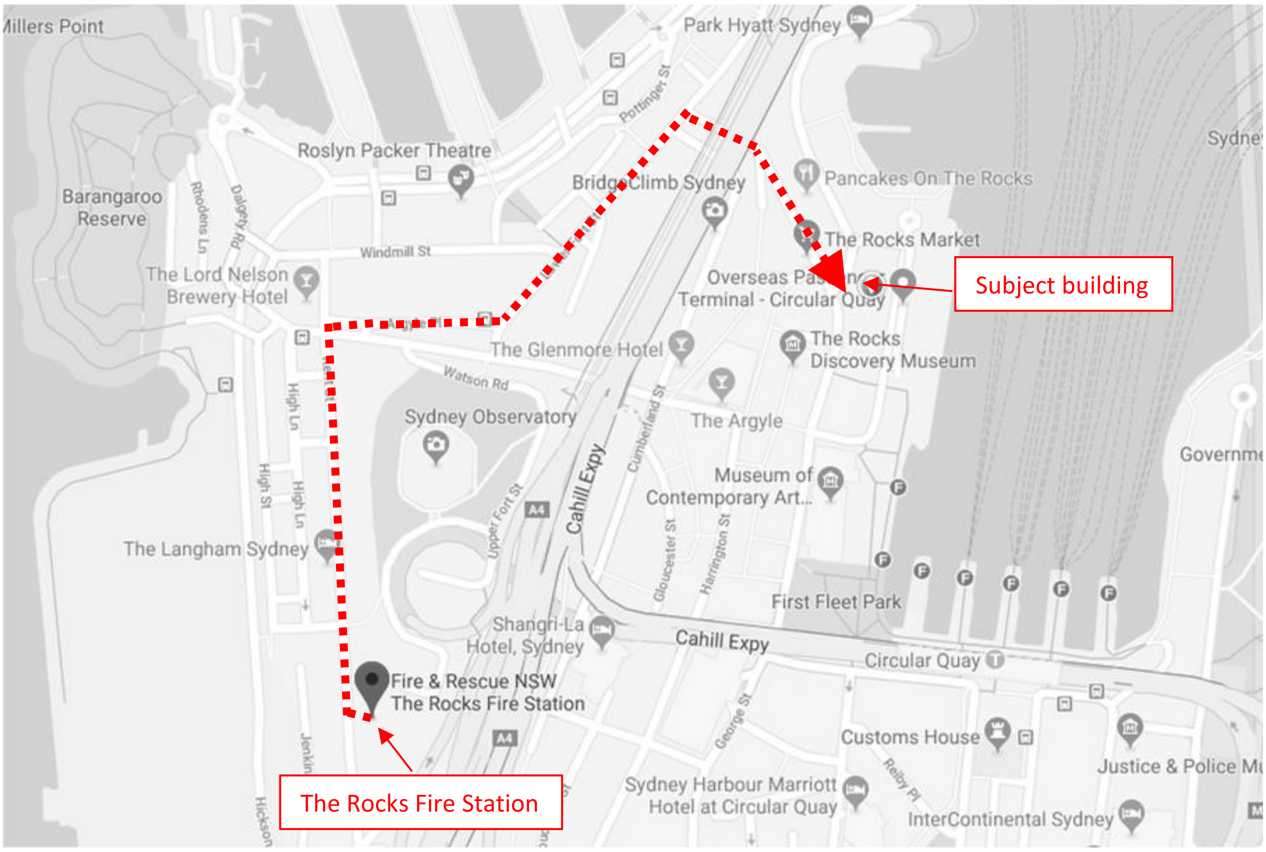


Figure 2 : Distance to closest Fire Station – The Rocks' Fire Station - approximately 4 minutes – (Google Maps)

3.1.2 Fire Brigade Site Access and Equipment

Fire brigade access is provided direct from Hickson Road as well as Circular Quay West, as depicted in Figure 2 with the Fire Indicator Panel (FIP) being accessible from the Circular Quay West.

Internal fire hydrants are provided with the pump room located on the Circular Quay West side of the building.

4. Fire Safety Measures

4.1 Suppression

Sprinklers shall be provided within the building in accordance with AS2118.1-2017.

4.2 Detection

The smoke detection and alarm system is to be provided in accordance with AS1670.1-2015 ignoring any concessions as result of the building being sprinkler protected.

4.3 Alarm

The building shall be provided with a Building Occupant Warning System throughout.

4.4 Hydrant System

The water supply and pump arrangement is to be upgraded to satisfy AS2118.1-2017, AS2419.1-2005 and/or AS2118.6-2012.

The internal fire hydrants are to be upgraded in accordance with AS2419.1-2005.

Fire services block plans shall be provided at the FIP.

4.5 Fire Hose Reel

The fire hose reel system serving Bay 1 may be omitted.

4.6 Fire Extinguisher

Portable fire extinguishers are to be installed throughout in accordance with AS2444-2001.

4.7 Emergency Lighting & Exit Signage

Emergency lighting and exit signage shall be provided throughout in accordance with AS2293.1-2005.

The final discharge level of stairs 2 and 5 shall be clearly highlighted within the stair, by signage stating ‘EXIT TO STREET’. The letters shall be at least 50 mm high and in a colour contrasting with the background.

4.8 Smoke Hazard Management

Medium temperature smoke seals (tested to resist smoke at 200°C for 30 minutes) shall be provided around the entire perimeter of the doors serving the area where Fire Stair 1 discharges (Bay 4).

Medium temperature smoke seals (tested to resist smoke at 200°C for 30 minutes) shall be provided around the entire perimeter of all the fire-isolated exit doors as well as any doors providing access between Bay 4 & 5.

4.9 Construction

The area on the ground floor where Fire Stair 1 discharges, shall be separated from the remaining ground floor area by construction that will resist the spread of smoke into the lobby. All doors serving this area shall be self-closing doors.

Any penetrations, openings and gaps between floors shall be adequately sealed with non-combustible materials that will resist the spread of smoke between floors.

4.10 Management in Use Plan

Commissioning and integrated function testing of all fire safety and protection systems including interfaces to ensure proper function must be undertaken.

All permanent staff working within the building shall be inducted in the evacuation procedures of the building. As part of this induction, staff shall be informed that in event of a fire alarm, it is essential that occupants evacuate immediately without delay. The induction requirement and the plan on how to implement it, shall be documented as part of a Management-in-use Plan. The Management-in-use Plan shall be listed as an essential fire safety measure on the building’s Fire Safety Schedule.

Fire Safety Measures

The proposed Fire Engineering Strategy for the building imposes the following requirements on the eventual building owner / manager:

- Maintain all active Fire Safety Systems in accordance with the relevant section of AS1851.
- Evacuation diagrams in accordance with AS 3745 to be provided.
- A no smoking policy is to be implemented in all areas.
- Regular evacuation drills to be conducted annually (minimum) within the building.
- General house-keeping must be undertaken to maintain the egress paths and exits clear in order to allow unimpeded travel.
- Where services are modified as part of a performance solution, these must be included in the maintenance and annual certification.

4.11 Safety in Design

The Fire Engineering Analysis is conducted on the basis that any ramifications for “Safety in Design” will be covered by the Risk Management Reporting of the relevant consultants/disciplines responsible for detailed documentation of works recommended by these disciplines including, but not limited to, the Architect and the relevant building services consultants. We will not produce a separate, standalone Risk Management Report for this discipline. We note that the OH&S legislation places particular obligations on the owners of property with respect to the management of OH&S issues arising from the construction, use, maintenance and demolition of plant and buildings.

5. Performance Solutions

5.1 Methodology

Satisfying the Performance Requirements of the BCA through Fire Engineering Performance Solutions can be undertaken using a variety of methods, as detailed in Table 6. Where Performance Solutions are undertaken using a Verification Methods, documents such as IFEG [2] and BS 7974-0 [4] have been used to define the appropriate type of analysis, i.e. Absolute – Qualitative – Deterministic.

Table 6: BCA Clauses – A0.2 Meeting the Performance Requirements and A0.5 Assessment Methodology

Clause A0.2	Clause A0.5
The Performance Requirements can only be satisfied by a— (a) Performance Solution; or (b) Deemed-to-Satisfy Solution; or (c) a combination of (a) and (b)	The following Assessment Methods, or any combination of them, can be used to determine that a Performance Solution or a Deemed-to-Satisfy Solution complies with the Performance Requirements, as appropriate: (a) Evidence to support that the use of a material, form of construction or design meets a Performance Requirement or a Deemed-to-Satisfy Provision as described in A2.2. (b) Verification Methods such as— i. the Verification Methods in the NCC; or ii. such other Verification Methods as the appropriate authority accepts for determining compliance with the Performance Requirements. (c) Expert Judgement. (d) Comparison with the Deemed-to-Satisfy Provisions

5.2 List of Performance Solutions

The following table shows the identified non-compliances with the BCA-2016 DtS provisions, which are addressed as Fire Engineered Performance Solutions within this report:

Table 7 : Summary of Performance Solutions

No.	Description of Performance Solution	BCA Clause	Performance Requirements	Assessment Method
1	Fire hazard properties associated with the timber floor / ceiling construction do not satisfy Specification C1.10 of the BCA.	C1.10, Spec. C1.10	CP4	A0.5(b)(ii)
2	Classifications between storeys results in class 5 & Class 9b uses that are not fire separated between storeys - Bay 2-4.	C2.9	CP2	A0.5(b)(ii)
	Requirements of C3.12 are not able to be satisfied due to the absence of fire rated construction associated with the floor construction between storeys.	C3.12	CP8	A0.5(b)(ii)
	Existing and proposed buildings elements such as floors, beams and columns do not achieve the required fire resistance level of construction.	Spec. C1.1	CP1, CP2, CP4	A0.5(b)(ii)

Performance Solutions

No.	Description of Performance Solution	BCA Clause	Performance Requirements	Assessment Method
	The floors and supporting structural elements do not satisfy Clause 2.2 of Specification C1.1.	Clause 2.2 of Spec. C1.1	CP1, CP2	A0.5(b)(ii)
	Services riser shafts do not achieve an FRL due to reliance on timber floor construction for support.	Spec. C1.1	CP1, CP2	A0.5(b)(ii)
	The exposed steel plates joining an existing concrete beam to a new concrete beam means that the floor it supports is unlikely to achieve the required FRL.	Spec. C1.1	CP1, CP2	A0.5(b)(ii)
3	Existing fire pump room within Bay 2 is not fire separated from the remainder of the building.	C2.12	CP2, CP6	A0.5(b)(ii)
4	Fire stair No 1 discharges to within the confines of the building contrary to the requirements of D1.7(b).	D1.7(b)	DP4, DP5	A0.5(b)(ii)
	Stair 2 & 5 incorporates rising and descending flights contrary to the requirements of Clause D2.4 of the BCA.	D2.4	DP5	A0.5(b)(ii)
5	Hydrant and sprinkler systems to share water supply infrastructure (single town main and 2 pumps) compliant with AS2118.6. Downstream of the pumps the manifold pipework will supply the Sprinkler system and the Hydrant system separately.	E1.3, AS2419.1, AS2118.6	EP1.3	A0.5(d)
6	Fire hose reels are proposed to be omitted from Bay 1.	E1.4, AS2441	EP1.1	A0.5(d)
7	Access to the fire pump room is not fire-isolated.	E1.3, AS2419.1	CP2, EP1.3, EP2.2	A0.5(b)(ii)
	The hydrant and sprinkler booster is not protected in accordance with AS2419.1.	E1.3, AS2419.1	CP2, E1.3	A0.5(b)(ii)

Performance Solutions

5.3 Performance Solution 1 – Fire Hazard Properties

5.3.1 Summary of Performance Solution

The following table provides a summary of the proposed Performance Solution.

Table 8 : Summary of Performance Solution 1

Description	Fire hazard properties associated with the timber floor / ceiling construction do not satisfy Specification C1.10 of the BCA.				
DtS Clause	C1.10, Specification C1.10	Performance Requirements	CP4	IFEG Sub-systems	SS – A SS – B SS – C SS – D SS – E
A0.3 - BCA Approach	Performance Solution	A0.5 - BCA Assessment Method	A0.5(b)(ii), A0.5(d)	Analysis Methodology	Qualitative Absolute / Comparative
Fire hazards	The hazard specific to this Performance Solution is that where timber floors, columns and beams are exposed, fire and smoke could develop and spread in the early stages via these exposed elements.				
Acceptance Criteria	To determine whether the Performance Solution is considered to meet the BCA Performance Requirements, the following will be demonstrated: ▪ Fire and smoke spread shall be adequately limited to ensure the safe evacuation of occupants.				
Description of Performance Solution	The approach used in this solution will be qualitative in nature and will use a deterministic absolute / comparative approach.				

5.3.2 DtS Provision

Clause C1.10 of the BCA outlines the fire hazard property requirements for materials.

The intent of the DtS clauses are outlined in the table below, taken from the BCA guide.

Table 9: BCA Guidance Document – DtS Provision and Intent

DtS Provision	Intent
C1.10 – Fire Hazard Properties	To stipulate the minimum fire hazard properties of materials susceptible to the effects of flame or heat. It is important that the spread of fire and the development of smoke be limited during a fire until building occupants have had time to evacuate.

To summarize the above, the key intent of the DtS provisions is to limit early fire and smoke development to provide safe egress.

5.3.3 Proposed Provisions

To facilitate the safe egress of occupants, the following are the proposed Fire Safety Provisions:

- Sprinklers shall be provided within the building to meet AS2118.1-2017.
- The water supply and pump arrangement is to be upgraded to meet AS2118.1-2017 and/or AS2118.6-2012.

- The smoke detection and alarm system is to be provided in accordance with AS1670.1-2015 ignoring any concessions as result of the building being sprinkler protected.

5.3.4 Qualitative Assessment

It is evident that the intent of the BCA is to limit the rapid development of fire, smoke and other toxic gases, during the early stages of a fire to allow a sufficient amount of time for occupants to safely evacuate. Walls and ceilings that are lined with hazardous materials could facilitate rapid fire spread and / or develop significant amounts of smoke during the early stages of a fire. This early fire and smoke spread could cause untenable conditions for occupants before they are able to evacuate. Therefore, the materials that form the linings of the walls and ceilings should be of a material that limits fire and smoke development to a degree necessary to facilitate occupant evacuation.

In the subject heritage building, the floor / ceiling structures (including the supporting columns) that separate the levels are of timber construction, with the exception of Bay 5 where certain parts of the floors are of concrete construction. Although combustible, timber is not considered very hazardous in terms of rapid fire and smoke spread when compared other materials such as plastics, polyurethane foams and rubbers. A majority of harder timber species that are typically used for flooring and structural elements generally comply with the fire hazard properties requirements of the BCA for walls and ceilings, with the exception that the timber is unlikely to achieve the correct Group Number. Specification C1.10 requires that wall and ceiling linings achieve a Group Number of 1 or 2, whereas timber typically achieves a Group Number of 3. In accordance with AS5637.1-2015, the Group Numbers are assigned as follows:

- Group 1—material that does not reach flashover when exposed to 100 kW for 600 s followed by exposure to 300 kW for 600 s.
- Group 2—material that reaches flashover following exposure to 300 kW within 600 s after not reaching flashover when exposed to 100 kW for 600 s.
- Group 3—material that reaches flashover in more than 120 s but within 600 s when exposed to 100 kW.
- Group 4—material that reaches flashover within 120 s when exposed to 100 kW.

From the above it can be seen that the purpose of the Group Number test is to determine when a material reaches flashover when exposed to a high radiant heat flux (at least 100 kW). A 100 kW heat flux is equivalent to the hot gases at ceiling level reaching an approximate temperature of 880°C (Stefan-Boltzmann equation). Therefore, this fire hazard property is more relevant to post-evacuation conditions considering that occupants are unlikely to survive such conditions regardless of whether the material reaches flashover or not. Timber does not typically ignite until it reaches a temperature of approximately 300°C [6] and the occupants are expected to evacuate the relevant areas prior to this temperature being achieved (refer to Performance Solution 2 for a detailed assessment).

In terms of smoke generation, timber produces low amounts of smoke (1.5% soot yield as per the SFPE Handbook compared to other combustible materials, ranging between 1.5%-25% [6]) and typically complies with the fire hazard properties of the BCA (i.e. average specific extinction area of less than 250 m^2/kg). Therefore, in terms of limiting the amount of smoke in the early stages of a fire, the timber floor / ceiling structure is expected to perform as well as a BCA DtS compliant design.

Additionally, the building will be provided with a voluntary sprinkler system that is expected to limit any fire spread within the building. The BCA does permit materials with a Group Number of 3 in sprinkler protected buildings, however the sprinkler system is treated as a voluntary measure and as such the sprinkler system is ignored for the purpose of determining BCA DtS compliance. Nonetheless, it is expected to limit fire spread via the ceiling material to degree that is at least equivalent to that of a BCA DtS compliant design.

Furthermore, the smoke detection and alarm system installed in accordance with AS1670.1-2015, is expected to provide the occupants with an early warning before the timber floor / ceiling structures are exposed to conditions that will facilitate significant fire spread.

5.3.5 Conclusion

Based on the qualitative assessment undertaken, it has been demonstrated that fire and smoke spread will be adequately limited to a degree necessary to facilitate the safe evacuation of occupants. As such Performance Requirement CP4 is considered to be met.

CP4	
To maintain tenable conditions during occupant evacuation, a material and an assembly must, to the degree necessary, resist the spread of fire and limit the generation of smoke and heat, and any toxic gases likely to be produced, appropriate to -	
a) the evacuation time; and	Timber is not expected to facilitate rapid fire spread during the early stages when occupants are evacuating. Timber limits early smoke spread to a degree that is equivalent to a BCA DtS compliant design.
b) the number, mobility and other characteristics of occupants; and	These characteristics were considered as part of this assessment. The number of occupants are not considered to be excessive due to the small size of the building and the relevant compartments.
c) the function or use of the building; and	Consideration was given to the Class 5 (office) and Class 9b (education) uses.
d) any active fire safety systems installed in the building.	Building is provided with a voluntary sprinkler system which is expected to limit fire spread and as a result also limit smoke spread.

5.4 Performance Solution 2 – Fire Resistance Level (FRL) of Floors / Ceilings

5.4.1 Summary of Performance Solution

The following table provides a summary of the proposed Performance Solution.

Table 10 : Summary of Performance Solution 2

Description	Classifications between storeys results in class 5 & Class 9b uses that are not fire separated between storeys - Bay 2-4. Requirements of C3.12 are not able to be satisfied due to the absence of fire rated construction associated with the floor construction between storeys. Existing and proposed buildings elements such as floors, beams and columns do not achieve the required fire resistance level of construction. The floors and supporting structural elements do not satisfy Clause 2.2 of Specification C1.1. Services riser shafts do not achieve an FRL due to reliance on timber floor construction for support. The exposed steel plates joining an existing concrete beam to a new concrete beam means that the floor it supports is unlikely to achieve the required FRL.					
DtS Clause	C1.1, Specification C1.1, C2.9, C3.12, Clause 2.2 of Specification C1.1		Performance Requirements	CP1, CP2, CP4, CP8	IFEG Sub-systems	SS – A SS – B SS – C SS – D SS – E SS – F
A0.3 - BCA Approach	Performance Solution	A0.5 - BCA Assessment Method	A0.5(b)(ii)	Analysis Methodology	Quantitative Absolute	
Fire hazards	The hazard specific to this Performance Solution is that the timber floor / ceiling construction as well as supporting columns and beams may not achieve the required fire resistance and therefore may eventually lead to fire spread between floors. Similarly, the exposed steel that joins the existing concrete slab to the new concrete slab, may also reduce the ability of the floor to achieve the required FRL.					

Acceptance Criteria	Fire spread shall be adequately limited, and structural stability shall be maintained to a degree necessary to: ▪ Facilitate occupant evacuation; and ▪ Facilitate fire brigade intervention; and ▪ Prevent collapse onto adjoining properties. To determine whether the Performance Solution is considered to meet the BCA Performance Requirements in terms of occupant evacuation, the following will be demonstrated: • **Design Fire Scenario** - The Available Safe Evacuation Time (ASET) shall be greater than the Required Safe Evacuation Time (RSET) whilst incorporating a 1.5 safety factor. ASET > RSET x 1.5 • **Redundancy Fire Scenario** - The Available Safe Evacuation Time (ASET) shall be greater than the Required Safe Evacuation Time (RSET) with no safety factor. ASET > RSET
Description of Performance Solution	The approach used in this solution will be quantitative in nature and will use a deterministic absolute approach.

5.4.2 DtS Provision

Clauses C1.1, C2.9 and C3.12 of the BCA outline the requirements for the fire resistance required of the floors separating the levels to limit fire spread between floors. For class 5 and 9b buildings, an FRL of 120/120/120 would be typically required by the BCA DtS Provisions for floors. The subject building being a building of heritage significance, will have exposed timber floor / ceiling structures supported by timber beams and columns. These timber floors are not expected to achieve the required FRL of 120/120/120 and as such, a performance based assessment was undertaken in this section to demonstrate that the relevant Performance Requirements of the BCA have been satisfied.

The intent of the DtS clauses are outlined in the table below, taken from the BCA guide.

Table 11: BCA Guidance Document – DtS Provision and Intent

DtS Provision	Intent
C1.1 – Type of construction required	To establish the minimum fire-resisting construction required for Class 2-9 buildings.
C2.9 – Separation of classifications in different storeys	To minimise the risk of a fire in one classification causing the failure of building elements in another classification in a different storey.
C3.12 – Openings in floors and ceilings for services	To limit the spread of fire through service openings in floors and ceilings required to resist the spread of fire.
Clause 2.2 of Specification C1.1 – Support of another part	To minimise the risk that a building element required to have a fire-resistance level (FRL) will fail during a fire due to the failure of another element required to give it vertical or lateral support.

As per Performance Requirements CP1, CP2 and CP8, the BCA uses terms such as “to the degree necessary” and “appropriate to”. As such, the BCA recognises that fire spread and structural collapse cannot always be avoided indefinitely, but in fact needs to be avoided or resisted for a period of time that is appropriate to support the safe evacuation of occupants, fire brigade intervention and the protection of adjoining property.

To summarize the above, the key intent of the DtS provisions is to adequately limit the spread of fire between floors and structural collapse to the degree necessary. This is to ensure occupants have sufficient time to exit the building and to ensure fire brigade intervention is facilitated and that the adjoining property will be protected.

5.4.3 Proposed Provisions

To facilitate the safe egress of occupants and fire brigade intervention, the following fire safety measures are proposed:

- Sprinklers shall be provided within the building to meet AS2118.1-2017.
- The water supply and pump arrangement is to be upgraded to meet AS2118.1-2017 and/or AS2118.6-2012.
- The smoke detection and alarm system is to be provided in accordance with AS1670.1-2015 ignoring any concessions as result of the building being sprinkler protected.
- The building shall be provided with a Building Occupant Warning System throughout.
- All permanent staff working within the building shall be inducted in the evacuation procedures of the building. As part of this induction, staff shall be informed that in event of a fire alarm, it is essential that occupants evacuate immediately without delay. The induction requirement and the plan on how to implement it, shall be documented as part of a Management-in-use Plan.

5.4.4 Quantitative Assessment

From the intent of the BCA it is evident that to satisfy the identified Performance Requirements of the BCA, it must be shown that fire spread and structural collapse is adequately such that the following is satisfied in the event of a credible fire scenario:

- Safe evacuation of occupants; and
- Safe fire brigade intervention; and
- Prevent damage to adjoining properties.

Fire Spread and Structural Collapse

It is considered that structural failure and fire spread would be adequately limited by the voluntary sprinkler system. The sprinkler system is expected to limit the temperatures within the compartment to less than 200°C [22]. Such temperatures are not considered sufficient to affect the timber floor / ceiling structure and therefore fire spread to other compartments and structural failure would not be expected. Sprinkler systems are well known to be reliable and as such an uncontrolled fire would be an unlikely event. The sprinkler system is expected to extinguish or at least control the fire. The limited fire size will reduce to hazards for occupants and the attending fire brigade significantly. As such, it is considered that fire spread and structural collapse would be adequately limited to degree necessary to facilitate the safe evacuation of occupants and fire brigade intervention.

This method of meeting the Performance Requirements via active systems in lieu of passive fire resistance is considered consistent with the Guide to the BCA which states “it may be found by a building proponent using an Alternate Solution that FRLs to building elements are not necessary as other means, such as the use of active systems, satisfy the Performance Requirements”. This is also evident in Clause C2.6 of the BCA which permits no vertical separation between external openings in sprinkler protected building. It is considered that the BCA recognises the reliability and effectiveness of sprinkler system to prevent fire spread.

In the unlikely event that the sprinklers fail to operate, the external walls are constructed of masonry and as such are expected to resist the effects of a fire for a significant amount of time to prevent damage to adjoining properties. The attending fire brigade would then be able to reduce the fire hazard using the fire hydrant system to further reduce the risk of collapse on to the adjoining properties.

Occupant Evacuation

The aim of the provisions in Section 5.4.3 and the fire safety strategy is to suppress the fire and to provide early detection and alarm of a fire scenario to allow occupants to evacuate safely. Within this section we provided a summary of the quantitative analysis which demonstrates safe egress. Appendix 3 and 4, detail the evacuation assessment and smoke and fire modelling respectively.

Appendix 4 details the fire and smoke analysis. Within the appendix, a zone model has been completed of a typical level, and a considered fire scenario (Refer to Appendix 4 for more details). The intent of this analysis is to demonstrate that for a fire in a given room on a floor within the building, fire and smoke spread would be adequately limited to facilitate occupant evacuation and fire brigade intervention.

A summary of the Available Safe Evacuation Time (ASET) and events, is tabulated below. There is a discussion around the criteria detailed below in Appendix 4.

Table 12: Design Fire Scenario - Summary of ASET and Events

Criteria	Criteria	Time	Discussion
Convective heat	120 °C	150 s	At this point everyone has left the room of fire origin.
Radiant	200 °C	190 s	At this point everyone has left the room of fire origin.
Visibility	10m	70 s	At this point everyone has left the room of fire origin.
Smoke Layer	2m	70 s	At this point everyone has left the room of fire origin.
Structural Stability Spread of fire to other compartments	300 °C	230 s	At this point everyone has left the building.

Table 13: Redundancy Fire Scenario - Summary of ASET and Events

Criteria	Criteria	Time	Discussion
Convective heat	120 °C	150 s	At this point everyone has left the room of fire origin.
Radiant	200 °C	180 s	At this point everyone has left the room of fire origin.
Visibility	10m	70 s	At this point everyone has left the room of fire origin.
Smoke Layer	2m	70 s	At this point everyone has left the room of fire origin.
Structural Stability Spread of fire to other compartments	300 °C	210 s	At this point everyone has left the building.

A comparison between the ASET and RSET are shown below in the tables. The ASET for both fire scenarios were compared to the RSET. A Margin of Safety of 1.5 x RSET has been incorporated in the Design Fire Scenario.

Table 14: Design Fire Scenario - Summary of ASET vs RSET

Criteria	Criteria	ASET	RSET x 1.5	Pass/Fail
Convective heat	120 °C	150 s (Room of fire origin)	62 s (Room of fire origin)	YES
Radiant	200 °C	180 s (Room of fire origin)	62 s (Room of fire origin)	YES
Visibility	10m	70 s (Room of fire origin)	62 s (Room of fire origin)	YES
Structural Stability Spread of fire to other compartments	300 °C	230 s	213 s (Entire building)	YES

Table 15 : Redundancy Fire Scenario - Summary of ASET vs RSET

Criteria	Criteria	ASET	RSET	Pass/Fail
Convective heat	120 °C	150 s (Room of fire origin)	41 s (Room of fire origin)	YES
Radiant	200 °C	190 s (Room of fire origin)	41 s (Room of fire origin)	YES
Visibility	10m	70 s (Room of fire origin)	41 s (Room of fire origin)	YES
Structural Stability Spread of fire to other compartments	300 °C	210 s	142 s (Entire building)	YES

Based on the above it is considered that the following has been demonstrated:

- Safe egress from the room of fire origin;
- Safe egress from the building before fire spread between compartments are likely to occur.

In addition, the analysis above did not take into consideration the reduction in compartment temperatures as a result of sprinkler operation. In the event of a fire, the sprinkler system is expected to limit the temperatures within the compartment to less than 200°C [22]. As per the above limiting criteria, such temperatures are not considered sufficient to affect the timber floor / ceiling structure and therefore fire spread to other compartments would not be expected.

Fire Brigade Intervention

Based on the assessment above, occupants are likely to have evacuated the building prior to the expected arrival of the fire brigade. As such, fire brigade activities would be limited to fire-fighting which may be carried out externally if the risk to enter the building is too great due to potential flashover conditions that could occur if the sprinklers failed to operate. If the sprinkler system operates effectively, the fire would be controlled and any fire spread to other compartments would be adequately limited.

Therefore, based on the provision of a sprinkler system, it is considered that fire spread would be adequately limited to a degree necessary to facilitate fire brigade intervention.

5.4.5 Conclusion

Based on the quantitative absolutistic assessment undertaken, it has been demonstrated that fire spread would be adequately limited such that occupants of the building are able to evacuate to a place of safety. Consequently, it is considered that Performance Requirements CP1, CP2, CP4 and CP8 have been satisfied in terms of the BCA DtS non-compliances assessed.

CP1	
A building must have elements which will, to the degree necessary, maintain structural stability during a fire appropriate to -	
a) the function or use of the building; and	Safe egress has been demonstrated, which takes into consideration the occupancy type and population.
b) the fire load; and	The analysis considered fire scenarios based on typical fuel loads expected in the subject occupancy type.
c) the potential fire intensity; and	Safe egress has been demonstrated to be complete prior to the fire reaching a hazardous intensity. Additionally, the sprinkler system will limit the intensity of the fire.
d) the fire hazard; and	The analysis considered fire scenarios based on typical hazards expected in the subject occupancy type.
e) the height of the building; and	All storeys were included in the evacuation analysis.
f) its proximity to other property; and	The subject building is sprinkler protected, which in combination with the fire resistant external masonry walls, is expected to prevent structural collapse onto the adjoining properties.
g) any active fire safety systems installed in the building; and	Sprinkler system to be provided in addition to BCA DtS requirements. The sprinkler system is expected to limit compartment temperatures to less than that required to compromise the structural adequacy of the subject timber floor / ceiling structure.
h) the size of any fire compartment; and	This item is not considered to be part of this Performance Solution.
i) fire brigade intervention; and	Occupant evacuation has been demonstrated to be complete prior to fire brigade intervention. This will limit the need for internal search and rescue for the fire brigade. The sprinkler system is expected to control the fire and limit any fire spread outside the compartment of fire origin. This will assist the fire brigade in managing the fire hazard.
j) other elements they support; and	Safe egress has been demonstrated to be complete prior to the likely time of structural failure of elements providing support to other elements.
k) the evacuation time.	Safe egress has been demonstrated to be complete prior to the likely time of structural failure.

CP2	
(a) A building must have elements which will, to the degree necessary, avoid the spread of fire -	
i) to exits; and	Safe egress has been demonstrated, and therefore this performance requirement has been met.
ii) between buildings; and	This is not considered as part of this performance solution.
iii) in a building.	Safe egress has been demonstrated, and therefore this performance requirement has been met.
(b) Avoidance of the spread of fire referred to in (a) must be appropriate to -	
i) the function or use of the building; and	Safe egress has been demonstrated, which takes into consideration the occupancy type and population.
ii) the fire load; and	The analysis considered fire scenarios based on typical fuel loads expected in the subject occupancy type.
iii) the potential fire intensity; and	Safe egress has been demonstrated to be complete prior to the fire reaching a hazardous intensity. Additionally, the sprinkler system will limit the intensity of the fire.
iv) the fire hazard; and	The analysis considered fire scenarios based on typical hazards expected in the subject occupancy type.
v) the number of storeys in the building; and	All storeys were included in the evacuation analysis.
vi) its proximity to other property; and	The subject building is sprinkler protected, which in combination with the fire resistant external masonry walls, is expected to prevent fire spread between the subject building and adjoining properties.
vii) any active fire safety systems installed in the building; and	Sprinkler system to be provided in addition to BCA DtS requirements. The sprinkler system is expected to limit compartment temperatures to less than that required to compromise the structural adequacy of the subject timber floor / ceiling structure.
viii) the size of any fire compartment; and	This item is not considered to be part of this Performance Solution.
ix) fire brigade intervention; and	Occupant evacuation has been demonstrated to be complete prior to fire brigade intervention. This will limit the need for internal search and rescue for the fire brigade. The sprinkler system is expected to control the fire and limit any fire spread outside the compartment of fire origin. This will assist the fire brigade in managing the fire hazard.
x) other elements they support; and	Safe egress has been demonstrated to be complete prior to the likely time of structural failure of elements providing support to other elements.
xi) the evacuation time.	Evacuation modelling has been completed and compared with the zone modelling, to demonstrate that safe egress.

Performance Solutions

CP4		
To maintain tenable conditions during occupant evacuation, a material and an assembly must, to the degree necessary, resist the spread of fire and limit the generation of smoke and heat, and any toxic gases likely to be produced, appropriate to—		
a)	the evacuation time; and	Evacuation modelling has been completed and compared with the zone modelling, to demonstrate that safe egress.
b)	the number, mobility and other characteristics of occupants; and	The number, mobility and other characteristics of occupants were considered as part of the evacuation modelling.
c)	the function or use of the building; and	Safe egress has been demonstrated, which takes into consideration the occupancy type and population.
d)	any active fire safety systems installed in the building.	Sprinkler system to be provided in addition to BCA DtS requirements. The sprinkler system is expected to limit fire and smoke spread via the subject timber materials.

CP8		
Any building element provided to resist the spread of fire must be protected, to the degree necessary, so that an adequate level of performance is maintained—		
a)	where openings, construction joints and the like occur; and	The timber floor / ceiling structure does not achieve an FRL and as such protecting openings, construction joints and like to achieve an FRL, would not provide a benefit. Evacuation modelling has been completed and compared with the zone modelling, to demonstrate that safe egress completed prior to the timber structure.
b)	where penetrations occur for building services.	The timber floor / ceiling structure does not achieve an FRL and as such protecting penetrations to achieve an FRL, would not provide a benefit. Evacuation modelling has been completed and compared with the zone modelling, to demonstrate that safe egress completed prior to the timber structure.

5.5 Performance Solution 3 – Pump Room Fire Separation

5.5.1 Summary of Performance Solution

The following table provides a summary of the proposed Performance Solution.

Table 16 : Summary of Performance Solution 3

Description	Existing fire pump room within Bay 2 is not fire separated from the remainder of the building.					
DtS Clause	C2.12		Performance Requirements	CP2, CP6	IFEG Sub-systems	SS – A SS – C SS – D SS – E
A0.3 - BCA Approach	Performance Solution	A0.5 - BCA Assessment Method	A0.5(b)(ii)	Analysis Methodology	Qualitative Absolute	
Fire hazards	The hazard specific to this Performance Solution is that fire spread may occur between the pump room and the rest of the building. This could also affect the operation of emergency equipment during a fire.					
Acceptance Criteria	Fire spread shall be adequately limited between the pump room and the rest of the building to ensure that: ▪ Occupant evacuation is safely facilitated; and ▪ Emergency equipment in the pump room continue to operate to the degree necessary.					
Description of Performance Solution	The approach used in this solution will be qualitative in nature and will use a deterministic absolute approach.					

5.5.2 DtS Provision

Clause C2.12 of the BCA outlines the requirements regarding the separation of equipment such as on-site fire pumps.

The intent of the DtS clauses are outlined in the table below, taken from the BCA guide.

Table 17: BCA Guidance Document – DtS Provision and Intent

DtS Provision	Intent
C2.12 – Separation of equipment	To limit the spread of fire from service equipment having a high fire hazard or potential for explosion and to ensure emergency equipment continues to operate during a fire.

As per the above, the key intent of the DtS provisions is to limit fire spread to the degree necessary to facilitate the safe evacuation of occupants and to maintain the operation of emergency equipment required during a fire.

5.5.3 Proposed Provisions

To limit fire spread and to facilitate the safe egress of occupants, the following are the proposed Fire Safety Provisions:

- Sprinklers shall be provided within the building to meet AS2118.1-2017.
- The water supply and pump arrangement is to be upgraded to meet AS2118.1-2017 and/or AS2118.6-2012.

- The smoke detection and alarm system is to be provided in accordance with AS1670.1-2015 ignoring any concessions as result of the building being sprinkler protected.

5.5.4 Qualitative Assessment

The BCA DtS Provisions require emergency equipment such as fire pumps, to be fire separated from the rest of the building in accordance with AS2419.1-2005. This requirement according to the Guide to the BCA, is to address the potential risk of fire spread from hazardous equipment to the rest of the building, and to ensure emergency equipment continues to operate during a fire that originates in other parts of the building.

The fire pump room in the subject building is located on the Ground Floor of Bay 2 as shown in the figure below. The pump room is not proposed to be enclosed by fire resisting construction, however the building will be protected by a sprinkler system in accordance with AS2118.1-2017. In the event of a fire the sprinkler system is expected to extinguish or at least suppress the growth of the fire. Studies [22] have shown that compartment temperatures associated with sprinkler-controlled fires generally do not exceed 200°C. Outside the immediate vicinity of the fire and beyond the fire room, gas temperatures will decrease until the gas temperature is below the sprinkler activation temperature as more sprinklers will activate. Hence the sprinkler system acts to cool the upper smoke layer and wet adjacent combustibles and partitions helping to prevent the fire from spreading beyond the area of origin.

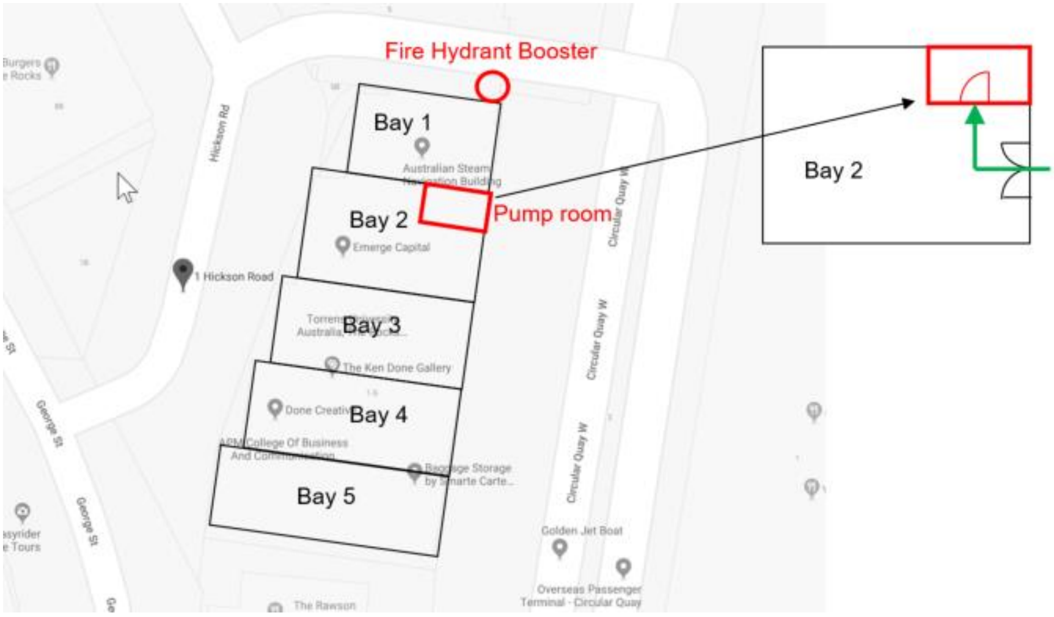


Figure 3: Location of pump room

In accordance with AS2419.1-2005, in buildings that are protected by sprinkler systems, pump rooms are not required to be enclosed by fire resisting construction. As such, the pump room of the subject building would typically comply with the AS2419.1-2005 and hence comply with the BCA. However, the sprinkler system is treated as a voluntary measure and as such the sprinkler system is ignored for the purpose of determining BCA DtS compliance. It should still be noted that from an AS2419.1-2005 perspective, the subject pump room would comply. Therefore, the standard implies that a sprinkler system would address the risk of fire spread between the pump room and the rest of the building to degree that would negate the need for the enclosure to be fire resistant. On that basis, it is considered that the subject pump room being in a sprinkler protected building, would satisfy the relevant Performance Requirements CP2 and CP6 of the BCA. However, a scenario where the sprinkler system fails to operate is considered below as part of a redundancy analysis.

Firstly, it should be noted that the likelihood of the sprinkler system failing to operate would be very low. Statistics from the National Fire Protection Association (NFPA), as published by [Hall], provides recorded statistics on buildings fitted with automatic fire sprinkler systems between the years 2003-2007 in the United States. Based on the NFPA data, when sprinklers operate, they are effective 97 % of the time, resulting in a combined performance of operating effectively in 89 % of all reported fires where sprinklers were present in the fire area and the fire was large enough to activate them. The reliability of sprinkler systems in Australia and New Zealand is generally significantly higher (greater than 98%) than in the US, as researched by Marryatt [23]. Therefore, it is considered that sprinkler systems provide a reliable means of limiting fire spread and reducing the hazards from a fire.

In the unlikely event that the sprinkler system failed to operate, it is considered that a fire originating outside of the pump room on the Ground Floor, could potentially damage the hydrant pumps and stop them from operating effectively. However, in such a fire scenario the operation of the pumps would not be considered necessary given that hydrant coverage to the Ground Floor of Bay 2 is provided via an external hydrant (booster assembly) that does not require assistance from internal pumps to supply water at the appropriate pressures. Coverage to this area would be provided by an external hose connected to the fire brigade pumping appliance which is supplied by the town's main via the hydrant booster assembly's suction points. Therefore, in this fire scenario it is expected that a fire outside the pump room would not impede fire brigade intervention.

In terms of addressing the impact on occupant evacuation, a fire originating within the pump room would need to be considered. Due to the lack of combustible materials, a fire in a pump room is expected to be an unlikely event. Equipment within a pump room consist mainly of metallic parts such as pump housings, pipes and diesel engines that would be difficult to ignite. Being diesel powered pumps, small amounts of diesel would be stored within adjoining fuel tanks, however the diesel fuel itself would not be exposed and would therefore also be difficult to ignite. In the event that a fire occurred within the pump room, it is expected that the smoke detection system would provide the occupants with an early warning to evacuate prior to the fire growing to a significant size.

Therefore, it is considered that the subject design would adequately limit fire spread between the pump room and the rest of the building to a degree necessary to facilitate occupant evacuation and fire brigade intervention.

5.5.5 Conclusion

Based on the qualitative assessment undertaken, it has been demonstrated that fire spread will be adequately limited to a degree necessary to facilitate the safe evacuation of occupants and fire brigade intervention. As such Performance Requirements CP2 and CP6 are considered to be satisfied in terms of the BCA DtS departure assessed.

CP2	
(a) A building must have elements which will, to the degree necessary, avoid the spread of fire -	
i) to exits; and	The assessment has demonstrated that the sprinkler system will limit fire spread between the pump room and the rest of the building to the degree necessary.
ii) between buildings; and	This is not considered as part of this performance solution.
iii) in a building.	The assessment has demonstrated that the sprinkler system will limit fire spread between the pump room and the rest of the building to the degree necessary.
(b) Avoidance of the spread of fire referred to in (a) must be appropriate to -	
i) the function or use of the building; and	The assessment takes into consideration the function and use of the building.

CP2	
ii) the fire load; and	The analysis considered fire scenarios based on typical fuel loads expected in the subject pump room.
iii) the potential fire intensity; and	Safe egress has been demonstrated to be complete prior to the fire reaching a hazardous intensity. Additionally, the sprinkler system will limit the intensity of the fire.
iv) the fire hazard; and	The analysis considered fire scenarios based on typical hazards expected in the subject pump room.
v) the number of storeys in the building; and	This item is not considered to be part of this Performance Solution.
vi) its proximity to other property; and	This item is not considered to be part of this Performance Solution.
vii) any active fire safety systems installed in the building; and	Sprinkler system to be provided in addition to BCA DtS requirements. The sprinkler system is expected to limit fire spread between the pump room and the rest of the building to the degree necessary.
viii) the size of any fire compartment; and	This item is not considered to be part of this Performance Solution.
ix) fire brigade intervention; and	The sprinkler system is expected to limit fire spread between the pump room and the rest of the building to the degree necessary to facilitate fire brigade intervention. Hydrant coverage to this part of the building does not rely on the operation of the internal pumps.
x) other elements they support; and	The pump room enclosure does not provide support to other elements.
xi) the evacuation time.	Safe egress has been demonstrated to be complete prior to the fire reaching a hazardous intensity. The sprinkler system is expected to control the fire to provide additional time for evacuation.

CP6	
A building must have elements, which will, to the degree necessary, avoid the spread of fire from service equipment having -	
a) a high fire hazard; or	Pump rooms generally considered low fire hazards due to lack of easily ignitable materials. The sprinkler system addresses the hazard as per AS2419.1-2005.
b) a potential for explosion resulting from a high fire hazard	The sprinkler system addresses the hazard as per AS2419.1-2005.

5.6 Performance Solution 4 – Fire Stair Discharge

5.6.1 Summary of Performance Solution

The following table provides a summary of the proposed Performance Solution.

Table 18 : Summary of Performance Solution 4

Description	Stair 2 (Bay 4) & Stair 5 (Bay 3) incorporates rising and descending flights contrary to the requirements of Clause D2.4 of the BCA. Fire-isolated stair no. 1 discharges within the building on the ground floor of Bay 4.					
DtS Clause	D1.7(b), D2.4		Performance Requirements	DP4, DP5	IFEG Sub-systems	SS – A SS – B SS – C SS – D SS – E
A0.3 - BCA Approach	Performance Solution	A0.5 - BCA Assessment Method	A0.5(b)(ii)	Analysis Methodology	Qualitative Absolute	
Fire hazards	The hazard specific to this Performance Solution is that occupants may mistakenly pass the level of discharge to a road or open space within Stairs 2 & 5. The hazard associated with Stair 1, is that occupants discharging within the building may be exposed to effects of a fire on that discharge level.					
Acceptance Criteria	The delay in finding the final discharge level from within stairs 2 & 5 shall not impede the safe evacuation of occupants. The occupants shall be adequately protected from the effects of fire and smoke from the discharge location of Fire Stair 1 until they reach a road or open space.					
Description of Performance Solution	The approach used in this solution will be qualitative in nature and will use a deterministic absolute approach.					

5.6.2 DtS Provision

Clause D1.7(b) of the BCA outlines the requirements regarding the discharge location of fire-isolated exit stairs.

Clause D2.4 outlines the requirements for the separation of rising and descending flights of stairs.

The intent of the DtS clauses are outlined in the table below, taken from the BCA guide.

Table 19: BCA Guidance Document – DtS Provision and Intent

DtS Provision	Intent
D1.7(b) – Travel via fire-isolated exits	To enable occupants to safely enter a fire-isolated exit which discharges to a safe location.
D2.4 - Separation of rising and descending stair flights	To minimise the risk that an occupant mistakenly passes the lowest storey providing escape when evacuating.

As per the above, the key intent of the DtS provisions is to provide the occupants with fire-isolated exits that can discharge them safely to a road or open space.

5.6.3 Proposed Provisions

To facilitate the safe egress of occupants, the following are the proposed Fire Safety Provisions:

- Sprinklers shall be provided within the building to meet AS2118.1-2017.
- The smoke detection and alarm system is to be provided in accordance with AS1670.1-2015 ignoring any concessions as result of the building being sprinkler protected.
- The final discharge level of stairs 2 and 5 shall be clearly highlighted within the stair, by signage stating ‘EXIT TO STREET’.
- Medium temperature smoke seals (tested to resist smoke at 200°C for 30 minutes) shall be provided around the entire perimeter of all the fire-isolated exit doors as well as any doors providing access between Bay 4 & 5.
- The area on the ground floor where Fire Stair 1 discharges, shall be separated from the remaining ground floor area by construction that will resist the spread of smoke into the fire exit.
- Medium temperature smoke seals (tested to resist smoke at 200°C for 30 minutes) shall be provided around the entire perimeter of the doors serving the area where Fire Stair 1 discharges.

5.6.4 Qualitative Assessment

Fire-isolated Stair Discharging within the Building

In accordance with Clause D1.7(b) of the BCA DTS Provisions, a fire-isolated stairway must discharge to a road or open space. This is to ensure that occupants are protected from a fire within the building until they reach a safe place (road or open space). If a fire-isolated stair discharges within a building, a fire on the level where the stair discharges could cause hazardous conditions and impede the evacuation along the final unprotected path to a road or open space.

In the proposed design, Fire Stair 1 discharges within the building on the Ground Floor of the building as shown in the figure below. Although considered to be within the building, the space where the stair discharges will be fully enclosed by non-combustible construction that separates the space from the rest of the building. The door will also be protected by Medium temperature smoke seals (tested to resist smoke at 200°C for at least 30 minutes). The building will also be sprinkler protected.

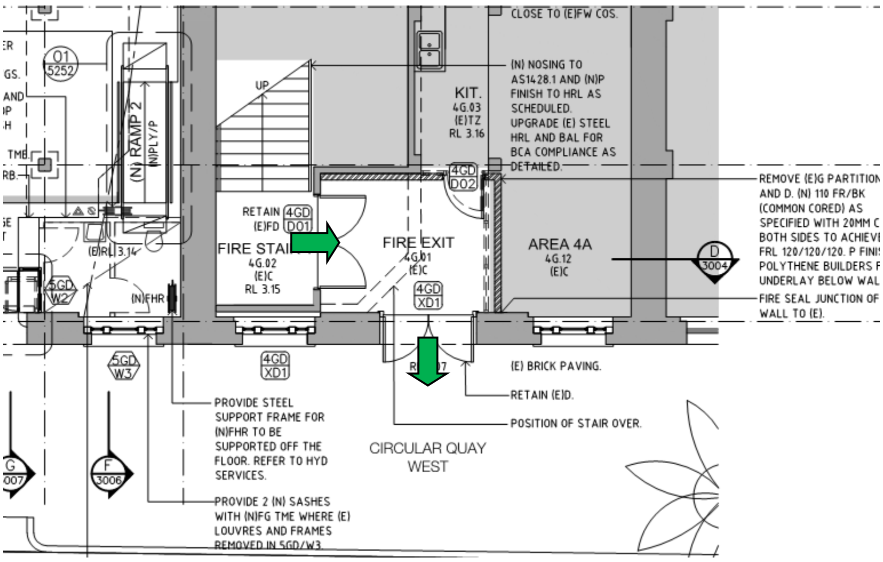


Figure 4: Fire Stair 1 discharge

In the event of a fire occurring on the Ground Floor in the space adjoining the discharge location, the sprinkler system is expected to extinguish or at least limit the spread of fire. Studies [22] have shown that compartment temperatures associated with sprinkler-controlled fires generally do not exceed 200°C. Therefore, the non-combustible construction that separates the fire affected room from the discharge space, would be considered sufficient to prevent fire spread to evacuating occupants. In addition, the door separating the subject spaces, will be provided with smoke seals that are capable of resisting smoke at 200°C for at least 30 minutes. The evacuation time estimated in Performance Solution 2 demonstrates that this amount of time would be sufficient for occupants to evacuate safely.

In the event that the door separating the subject spaces is obstructed in the open position, there may potential for smoke spread to the discharge location. However, such a scenario would be no different to a door being obstructed in the open position as part of a BCA DtS compliant exit. In a BCA DtS compliant design if the subject discharge location was separated from the rest of the building by fire resisting construction, the subject door could also be obstructed in the open position and smoke could spread into the stair. In the proposed design, the subject stair is separated by two sets of doors and would therefore require both to be obstructed in the open position. As such, occupants in the proposed design would be able to travel back up the stair to search for an alternative exit should the discharge location be compromised by smoke. Therefore, it is considered that occupants would be adequately protected from the effects of fire and smoke from the discharge location of Fire Stair 1 until they reach a road or open space.

In terms of fire brigade intervention, it is considered that the proposed design with Stair 1 discharging within the building will not impede fire brigade access. For this fire scenario (fire in the adjoining space on the Ground Floor), the attending fire brigade would be provided with multiple alternative access points via various Bays as well as Stair 2 within the same Bay. The attending fire brigade would achieve hydrant coverage from Stair 2 or from an external position using the booster supply and a pumping appliance. As such, with no hydrants provided within the subject Stair 1, access via the subject discharge area would not be required for hydrant access.

Separation of Rising and Descending Stairs

Rising and descending flights of stairs are required to be smoke separated to ensure occupants do not mistakenly pass the level of discharge to a road or open space. If the occupants cannot easily identify the final level of discharge, then their evacuation could be delayed.

In the proposed design, Stair 2 (Bay 4) and Stair 5 (Bay 3) have both rising and descending flights of stairs that discharge on Level 2 of the building onto Hickson Road. However, the final discharge level of stairs 2 and 5 shall be clearly highlighted within the stair, by signage stating 'EXIT TO STREET'. This signage is expected to help the occupants identify the final exit level and avoid any delay in evacuation. In addition, the window openings within the stair would assist occupants in identifying the final exit level as the road would be visible from within the stair.

In the unlikely event that occupants are unable to identify the final discharge level, occupants could continue beyond the level of discharge which could potential result in a minor delay in evacuation. However, this minor delay is not expected to impede the safe evacuation of occupants for the following reasons:

- The building is provided with a voluntary sprinkler system which is expected reduce the fire hazard and provide more time for evacuation; and
- The stair doors will be protected with smoke seals which in combination with the sprinkler system, will limit any significant smoke spread into the stair; and
- The building only has a rise-in-storeys of 5 and therefore if occupants pass the discharge level on the second floor, they could only travel another two storeys before realising they are travelling in the wrong direction.

Fire brigade access and intervention would be facilitated in a similar way. The signage in the stair would also assist the attending fire brigade with wayfinding within the stair.

5.6.5 Conclusion

Based on the qualitative assessment undertaken, it has been demonstrated that the occupants would be adequately protected from the effects of fire and smoke from the discharge location of Fire Stair 1 until they reach a road or open space and the delay in finding the final discharge level from within stairs 2 and 5 would not impede the safe evacuation of occupants. As such Performance Requirements DP4 and DP5 are considered to be satisfied in terms of the BCA DtS departures assessed.

DP4	
Exits must be provided from a building to allow occupants to evacuate safely, with their number, location and dimensions being appropriate to -	
a) the travel distance; and	Travel distances comply with the BCA DtS Provisions.
b) the number, mobility and other characteristics of occupants; and	The assessment considered the evacuation time from Performance Solution 2 which was based on the number, mobility and other characteristics of occupants.
c) the function or use of the building; and	The Performance Solution is not affected by the function or use of this building.
d) the height of the building; and	The assessment considered the rise-in-storeys of the building and demonstrated that safe egress would still be facilitated.
e) whether the exit is from above or below ground level.	This Performance Solution showed that the subject stairs with rising and descending stairs would still facilitate safe egress.

DP5	
To protect evacuating occupants from a fire in the building exits must be fire-isolated, to the degree necessary, appropriate to -	
a) the number of storeys connected by the exits; and	The assessment considered the rise-in-storeys of the building and demonstrated that safe egress would still be facilitated.
b) the fire safety system installed in the building; and	The building is provided with a voluntary sprinkler system which is expected to reduce the fire hazard significantly.
c) the function or use of the building; and	The Performance Solution is not affected by the function or use of this building.
d) the number of storeys passed through by the exits; and	The assessment considered the rise-in-storeys of the building and demonstrated that safe egress would still be facilitated.
e) fire brigade intervention.	This Performance Solution showed that fire brigade access and intervention would be facilitated via the measures that addressed occupant evacuation.

5.7 Performance Solution 5 – Hydrant Water Supply

5.7.1 Summary of Performance Solution

The following table provides a summary of the proposed Performance Solution.

Table 20 : Summary of Performance Solution 5

<table>
<tr><td>Description</td><td colspan="6">Hydrant and sprinkler systems to share water supply infrastructure (single town main and 2 pumps) compliant with AS2118.6. Downstream of the pumps the manifold pipework will supply the Sprinkler system and the Hydrant system separately.</td></tr>
<tr><td>DtS Clause</td><td colspan="2">E1.3, AS2419.1-2005, AS2118.6-2012</td><td>Performance Requirements</td><td>EP1.3</td><td>IFEG Sub-systems</td><td>SS – A
SS – C
SS – D
SS – F</td></tr>
<tr><td>A0.3 - BCA Approach</td><td>Performance Solution</td><td>A0.5 - BCA Assessment Method</td><td>A0.5(b)(ii), A0.5(d)</td><td>Analysis Methodology</td><td colspan="2">Qualitative
Absolute / Comparative</td></tr>
<tr><td>Fire hazards</td><td colspan="6">The hazard specific to this Performance Solution is that if the hydrant and sprinkler system is not designed in accordance with AS2118.6-2012, the operation of the sprinkler system may affect the performance of the hydrant system.</td></tr>
<tr><td>Acceptance Criteria</td><td colspan="6">The fire hydrant system shall be provided with a reliable water supply, to safely facilitate fire brigade intervention.</td></tr>
<tr><td>Description of Performance Solution</td><td colspan="6">The approach used in this solution will be qualitative in nature and will use a deterministic absolute / comparative approach.</td></tr>
</table>

5.7.2 DtS Provision

Clause E1.3 of the BCA outlines the requirements regarding fire hydrants systems and relevant design standards.

The intent of the DtS clauses are outlined in the table below, taken from the BCA guide.

Table 21: BCA Guidance Document – DtS Provision and Intent

DtS Provision	Intent
E1.3 – Fire hydrants	To require the installation of suitable fire hydrant systems to facilitate the fire brigade's firefighting operations.

As per the above, the key intent of the DtS provisions is to provide the attending fire brigade with a suitable fire hydrant system to facilitate firefighting operations.

5.7.3 Proposed Provisions

To facilitate fire brigade intervention, the following are the proposed Fire Safety Provisions:

- Sprinklers shall be provided within the building to meet AS2118.1-2017.
- The water supply and pump arrangement is to be upgraded to meet AS2419.1-2005 and/or AS2118.6-2012.
- The internal fire hydrants are to be upgraded in accordance with AS2419.1-2005.

5.7.4 Qualitative Assessment

In accordance with Specification E1.5 of the BCA, a combined sprinkler and hydrant system to AS2118.6-2012 may be provided in lieu of two separate systems. AS2118.6-2012 requires additional measures to ensure the operation of the sprinkler system does not affect the performance of the hydrant system. This includes measures such as the following:

- Sprinkler control assemblies within fire-isolated stairs on each level; and
- Water supplies having the capacity to address the demand of both systems simultaneously.

Sprinkler control assemblies provide for sprinkler isolation on each level of the building for maintenance and firefighting purposes. In the event of a fire, the attending fire brigade may require the sprinklers to be isolated in circumstances where the sprinkler system demand on the water supply is too great for the hydrant system to operate effectively. By isolating the sprinkler system, the fire brigade would be able to better control the flow and pressure from the hydrant hoses.

The requirement for water supplies to cater for both systems simultaneously will ensure that when the sprinkler system operates as designed, it would not affect the water supply for the hydrant system.

In the proposed design, the hydrant and sprinkler systems share the water supply infrastructure (single town main and 2 pumps) that is compliant with AS2118.6-2012. Downstream of the pumps the manifold pipework will supply the sprinkler system and the hydrant system separately. The isolation valve for the sprinkler system is provided within the sprinkler valve / pump room and therefore the need for individual sprinkler control assemblies on each level is not required. Therefore, if needed, the sprinkler system can be isolated in the pump room and the hydrant system would then continue to operate without being affected by the sprinkler system. It should be noted this would only be the case if the sprinklers are operating beyond design capacity. It is considered that this scenario where the fire is controlled by sprinklers would be less hazardous for the attending fire brigade when compared to a BCA DtS compliant solution that has a stand-alone hydrant system and is not sprinkler protected.

In terms of water supply capacity, the combined water supply in the proposed design will be designed in accordance with AS2118.6-2012. Therefore, the system is expected to be capable of supplying both systems simultaneously.

As such, it is considered that the fire hydrant will be provided with a reliable water supply to a degree necessary to facilitate fire brigade intervention.

5.7.5 Conclusion

Based on the qualitative assessment undertaken, it has been demonstrated that the fire hydrant system will be provided with a reliable water supply to a degree necessary to facilitate fire brigade intervention. As such Performance Requirement EP1.3 is considered to be satisfied in terms of the BCA DtS departure assessed.

EP1.3	
A fire hydrant system must be provided to the degree necessary to facilitate the needs of the fire brigade appropriate to -	
a) fire-fighting operations; and	The assessment demonstrates that the fire hydrant system would be provided with a reliable water supply to facilitate fire-fighting operations.
b) the floor area of the building; and	The floor area of the building is relatively small and would benefit the performance of combined sprinkler hydrant systems.
c) the fire hazard.	The voluntary sprinkler system should reduce the fire hazard significantly when compared to a BCA DtS compliant design with no sprinklers.

5.8 Performance Solution 6 – Omission of Fire Hose Reel from Bay 1

5.8.1 Summary of Performance Solution

The following table provides a summary of the proposed Performance Solution.

Table 22 : Summary of Performance Solution 6

Description	It is proposed to omit the fire hose reels from Bay 1 and provide portable fire extinguishers instead.					
DtS Clause	E1.4		Performance Requirements	EP1.1	IFEG Sub-systems	SS – A SS – C SS – D SS – E
A0.3 - BCA Approach	Performance Solution	A0.5 - BCA Assessment Method	A0.5(d) - Comparison with Deemed-to-satisfy provisions	Analysis Methodology	Qualitative Comparative	
Fire hazards	The hazard specific to this Performance Solution is that if the subject area is not provided with adequate fire-fighting measures for the occupants, then the opportunity to fight the fire when in its infancy, will be diminished.					
Acceptance Criteria	Occupants shall be provided with an appropriate means of undertaking an initial attack on a fire to a degree that is at least equivalent to a BCA DtS compliant design.					
Description of Performance Solution	The approach used in this solution will be qualitative in nature and will use a deterministic comparative approach.					

5.8.2 DtS Provision

Clause E1.4 of the BCA outlines the requirements regarding fire hose reels.

The intent of the DtS clauses are outlined in the table below, taken from the BCA guide.

Table 23: BCA Guidance Document – DtS Provision and Intent

DtS Provision	**Intent**
E1.4 – Fire hose reels	To require the installation of suitable fire hose reel systems to enable, where appropriate, a building's occupants to undertake initial attack on a fire.

As per the above, the key intent of the DtS provisions is to provide the occupants with an appropriate means of undertaking an initial attack on a fire.

5.8.3 Proposed Provisions

To facilitate the safe initial attack on a fire, the following are the proposed Fire Safety Provisions:

- Sprinklers shall be provided within the building to meet AS2118.1-2017.
- The smoke detection and alarm system is to be provided in accordance with AS1670.1-2015 ignoring any concessions as result of the building being sprinkler protected.
- Portable fire extinguishers are to be installed throughout in accordance with AS2441-2001.

- All permanent staff working within the building shall be inducted in the evacuation procedures of the building. As part of this induction, staff shall be informed that in event of a fire alarm, it is essential that occupants evacuate immediately without delay. The induction requirement and the plan on how to implement it, shall be documented as part of a Management-in-use Plan.
- The fire hose reel system serving Bay 1 may be omitted.

5.8.4 Assessment Methodology

This assessment was carried out using a comparative type of analysis where the proposed design was compared to a design that complies with the DtS Provisions of the BCA. This approach is in accordance with the BCA and the International Fire Engineering Guidelines.

The proposed design and the BCA DtS compliant design that were compared were considered identical with the exception of the following features:

Proposed Design

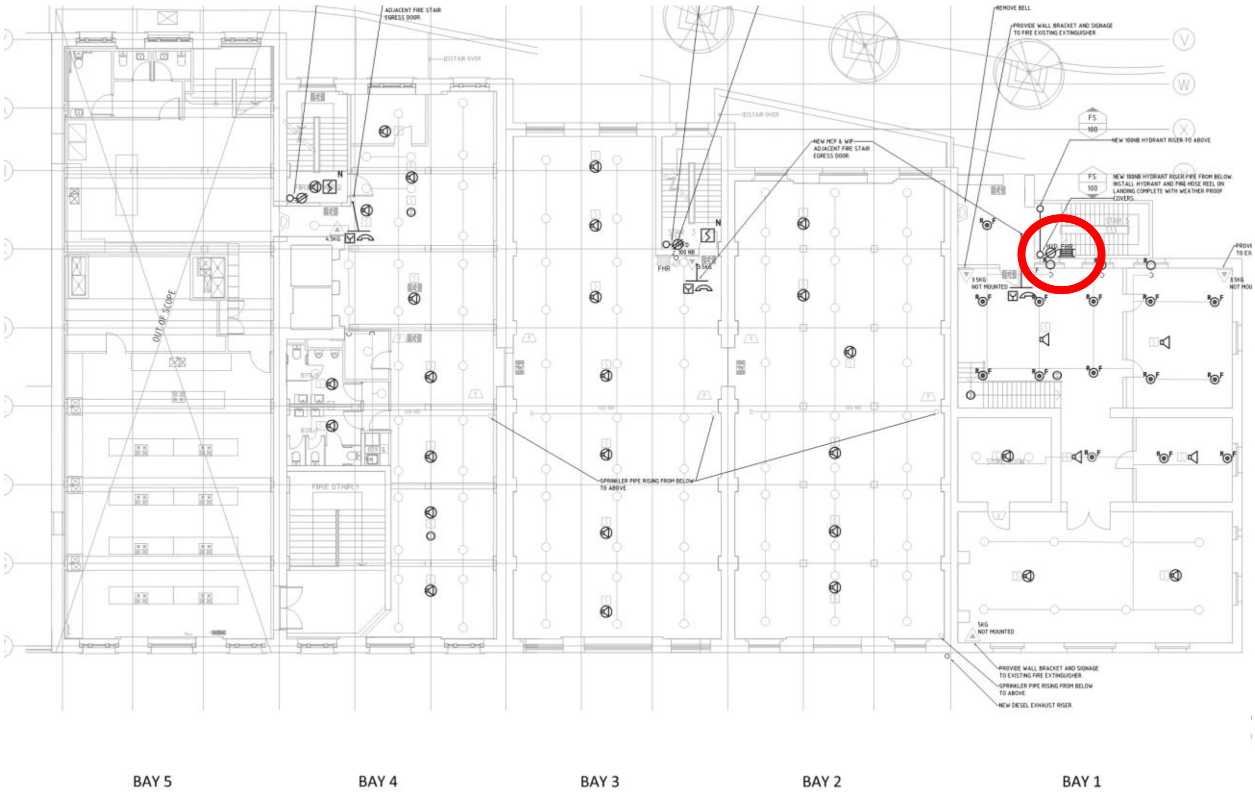
- Fire hose reel from Bay 1 omitted; and
- Sprinkler system provided throughout; and
- All permanent staff working within the building shall be inducted in the evacuation procedures of the building. As part of this induction, staff shall be informed that in event of a fire alarm, it is essential that occupants evacuate immediately without delay.

BCA DtS Compliant Design

- Fire hose reel provided for Bay 1; and
- No sprinkler system; and
- No specific training / induction in evacuation procedures.

5.8.5 Comparative Assessment

Fire hose reels provide occupants with means of undertaking an initial attack on a fire during its early stages of growth. Due to the continuous supply of water, fire hose reels are capable of extinguishing slightly larger fires when compared to portable fire extinguishers. In the proposed design, it is proposed to omit the fire hose reel from Bay 1 as shown in the figure below, due to the provision of a sprinkler system and portable fire extinguishers as well as other measures.



In the event of a fire with Bay 1, both the proposed and BCA DtS compliant design will have a means of undertaking an initial attack on a fire due to the provision portable fire extinguishers. Portable fire extinguishers are expected to enable the occupants to fight a range of fires whilst in its early stages of growth. The common ABE type extinguishers are suitable for the following types of fires:

- Class A – Paper, textiles, wood, most plastics and rubber
- Class B – Flammable liquids
- Class E – Electrically energized equipment

From the above, it can be seen that the common ABE type portable fire extinguishers can address the most common types of fires. Portable fire extinguishers would be more suitable for extinguishing electrical equipment when compared to other measures using water as an extinguishing agent. Therefore, in the early stages of the fire it is considered that the proposed design would provide the occupants with a means to fight the fire to a degree that is at least equivalent to that of BCA DtS compliant design.

In the event the fire grows to a size that is beyond the extinguishing capacity of portable fire extinguishers, the BCA DtS compliant design is provided with a fire hose reel system in Bay 1. The fire hose reel system is expected to be able to address a slightly larger fire, however as the fire size grows beyond the extinguishing capacity of extinguishers, the risk to occupant safety would increase significantly. Without proper training in the use of fire hose reels, the increase risk to occupant safety may outweigh the benefits of having a continuous water supply from a fire hose. Occupants that are not trained in the use of fire hose reels and that are not familiar with their location, may be delayed in responding to fight a fire due to them searching for the hose reel and learning how to use it at the time of the fire. This delay could result in a larger fire and hence occupants could be subjected to more hazardous conditions.

In the proposed design, if the fire grows beyond the extinguisher's capacity, the sprinkler system provided throughout would activate to extinguish or control the fire. A sprinkler system is considered far superior in extinguishing or controlling larger fires when compared to fire hose reels and would not subject the occupants to the effects of a fire in close proximity. In the proposed design with the sprinkler system operating, occupants are unlikely to feel the need to manually fight the fire and could simply evacuate whilst the sprinkler system controls the fire. Therefore, for larger fires, occupants in the proposed design would be subjected to less hazardous conditions given the major benefits of sprinkler protection.

Additionally, staff within the proposed design will be provided with specific evacuation training / inductions to ensure the building is evacuated without delay. As such, if the fire is not immediately extinguishable by a nearby extinguisher, occupants would be advised to evacuate immediately without delay and a secondary attempt using a fire hose reel would not be encouraged. Therefore, a fire hose reel system in this case would not provide any benefit given the evacuation strategy for the building.

5.8.6 Conclusion

Based on the comparative assessment undertaken, it has been demonstrated that the occupants in the proposed design would be provided with an appropriate means of undertaking an initial attack on a fire to a degree that is at least equivalent to a BCA DtS compliant design. As such Performance Requirement EP1.1 is considered to be satisfied in terms of the BCA DtS departure assessed.

EP1.1	
A fire hose reel system must be installed to the degree necessary to allow occupants to safely undertake initial attack on a fire appropriate to -	
a) the size of the fire compartment; and	The compartments are relatively small and the assessment has demonstrated the proposed design provides a means of undertaking a safe initial attack on the fire to a degree that is at least equivalent to a BCA DtS compliant design.
b) the function or use of the building; and	The assessment considered the function and the use of the building and it was demonstrated that portable fire extinguishers and a sprinkler system would provide an equivalent level of safety when compared to a BCA DtS compliant design.
c) any other fire safety systems installed in the building; and	The voluntary sprinkler system would be more effective at extinguishing or controlling larger fires when compared to a BCA DtS compliant design with a fire hose reel but no sprinklers.
d) the fire hazard.	The voluntary sprinkler system would reduce the fire hazard significantly when compared to a BCA DtS compliant design with no sprinklers.

5.9 Performance Solution 7 – Access to Hydrant Booster and Pump Room

5.9.1 Summary of Performance Solution

The following table provides a summary of the proposed Performance Solution.

Table 24 : Summary of Performance Solution 7

Description	Access to the fire pump room is not fire-isolated. The hydrant and sprinkler booster is not protected in accordance with AS2419.1-2005.					
DtS Clause	E1.3		Performance Requirements	EP1.3, CP2, EP2.2	IFEG Sub-systems	SS – A SS – C SS – D SS – F
A0.3 - BCA Approach	Performance Solution	A0.5 - BCA Assessment Method	A0.5(b)(ii)	Analysis Methodology	Qualitative Absolute	
Fire hazards	The hazard specific to this Performance Solution is that the attending fire brigade may not be provided with adequate access and protection to facilitate fire brigade intervention.					
Acceptance Criteria	The attending fire brigade shall be provided with safe access and protection to a degree necessary to facilitate fire brigade intervention.					
Description of Performance Solution	The approach used in this solution will be qualitative in nature and will use a deterministic absolute approach.					

5.9.2 DtS Provision

Clause E1.3 of the BCA and AS2419.1-2005 outline the requirements regarding fire hydrant systems. AS2419.1-2005 requires that access to the pump room be provided via a fire-isolated stair / passage. AS2419.1-2005 also requires that the hydrant booster if located along the external wall of the building, be protected by a fire resisting wall that extends 2m either side and 3m above the booster valves.

The intent of the DtS clauses are outlined in the table below, taken from the BCA guide.

Table 25: BCA Guidance Document – DtS Provision and Intent

DtS Provision	Intent
E1.3 – Fire hydrants	To require the installation of suitable fire hydrant systems to facilitate the fire brigade's firefighting operations.

It is evident from the above, that the key intent of the DtS provisions is to provide the attending fire brigade with safe access to the pump room and adequate protection around booster, to safely facilitate fire brigade intervention.

5.9.3 Proposed Provisions

To facilitate the safe egress of occupants, the following are the proposed Fire Safety Provisions:

- Sprinklers shall be provided within the building to meet AS2118.1-2017.

5.9.4 Qualitative Assessment

Access to the Pump Room

In accordance with AS2419.1-2005, access to the pump room is required to be fire-isolated. This requirement is there to ensure that the fire brigade personnel are adequately protected from a fire in the buildings when attempting to access the pump room. It is understood that the attending fire brigade may seek to access the pump room to monitor pump performance and to potentially shut the pumps down so that water pressure can be boosted and controlled manually via the external hydrant booster. Access to the pump room in this case may also be required to isolate the sprinkler system from the hydrant system.

In the proposed design, the pump room located on the Ground Floor in Bay 2, is accessed via a non-fire-isolated room as shown in the figure below.

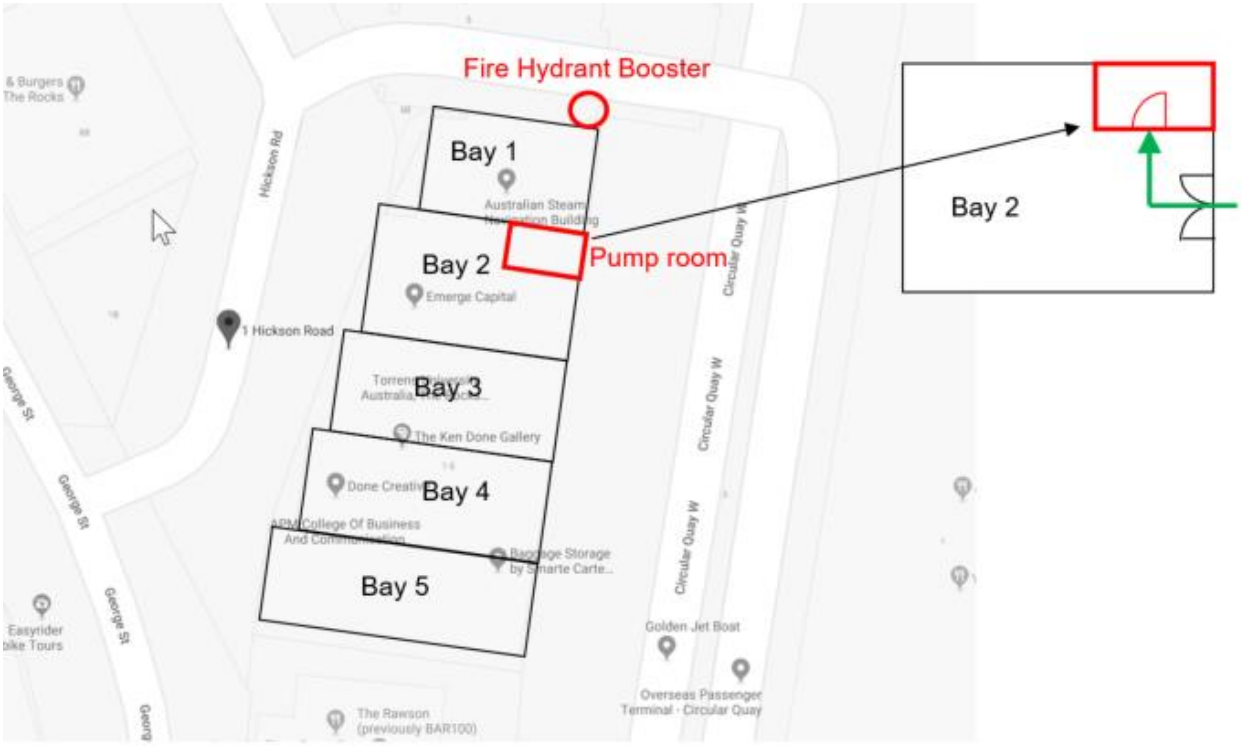


Figure 5: Pump room location and access

The building is however provided with a sprinkler system throughout in addition to the requirements of the BCA DtS Provisions. In the event of a fire on the Ground Floor of Bay 2, it is considered that the sprinkler system would extinguish or at least limit the spread of fire thereby significantly reducing the size of the fire and the hazard for the fire brigade when compared to a BCA DtS compliant building with no sprinklers. In Performance Solution 2, the fire size of a sprinkler controlled fire was estimated to be less than 0.3 MW which is well within the extinguishing capacity of an external fire hose (up to 16 MW at 10 L/s) according the Fire Brigade Intervention Model V2.2 published by AFAC. Therefore, given the proximity of the subject compartment of fire origin, the attending fire brigade would be in a position to extinguish the fire by approaching the fire from an external position with a hose connected to their pumping appliance supplied by the onboard water supply or could be supplied by the town's main via the booster as shown in Figure 6.

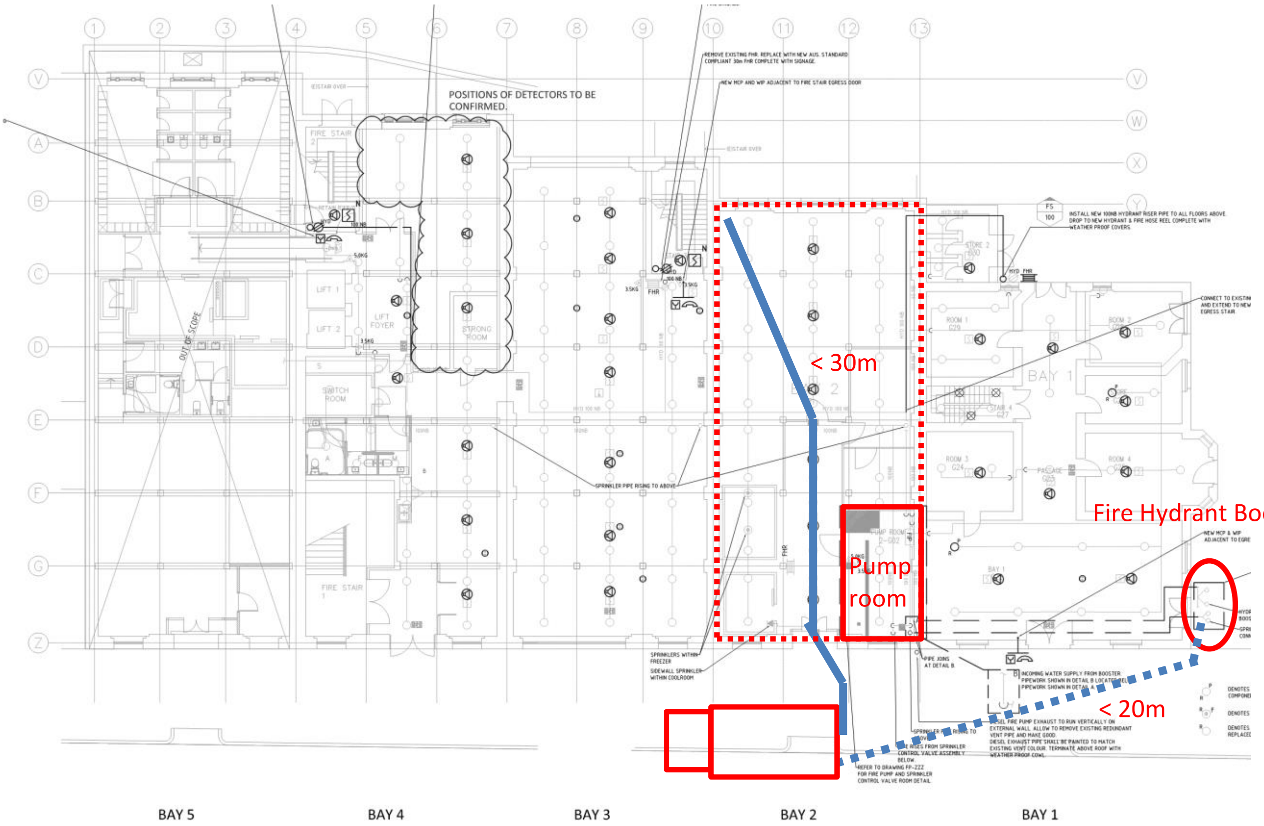


Figure 6: External hydrant coverage from a pumping appliance for Bay 2

In the event the sprinklers fail to operate, it is considered that the fire brigade could more safely fight the fire from an external position using a hose connected to a pumping appliance rather than enter the building to use internal hydrants during potential flashover conditions. The external hose would not rely on the internal pumps and therefore fire brigade access to the pump room would unlikely be required to fight the fire (refer to Figure 6).

Therefore, based on the assessment above, it is considered that fire brigade access is provided to a degree necessary to facilitate fire brigade intervention.

Fire Hydrant Booster Protection

AS2419.1-2005 requires that fire hydrant boosters when located along the external wall of a building, must be protected by a fire-resisting wall that extends 2m either side and 3m above the booster valves. The aim of his fire resisting construction is to provide the fire brigade with protection from a fire within the building whilst accessing the booster.

In the proposed design, the upgraded booster assembly is proposed to be located where the existing booster is located as shown in the figure below. There are two large openings (i.e. window and a door) on either side of the booster that are unprotected. However, it is considered that the sprinkler system provided throughout the building would afford the attending fire brigade with the required protection as discussed below.

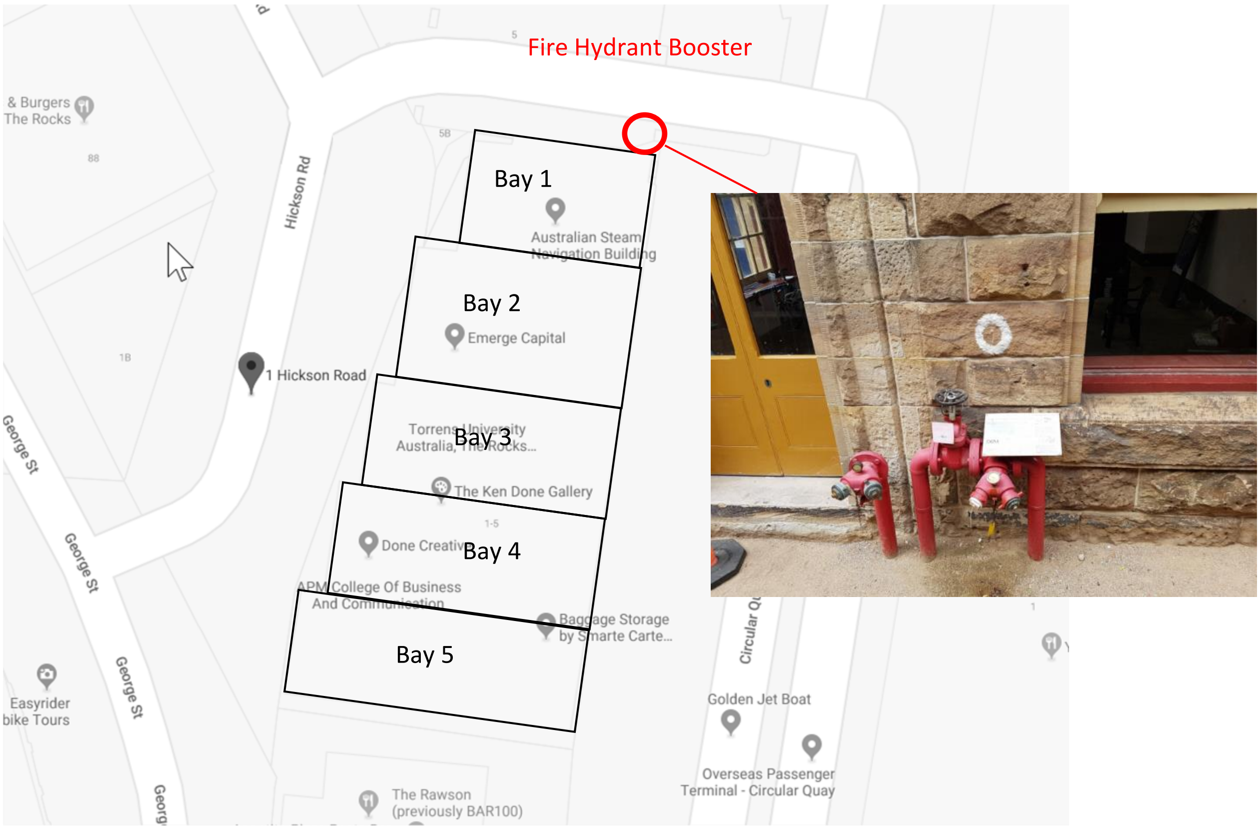


Figure 7: Fire Hydrant Booster location and wall configuration

In the event of a fire on the Ground Floor of Bay 1, the sprinkler system is expected to control the fire and reduce the temperatures within the compartment significantly. As previously discussed, studies [22] have shown that compartment temperatures associated with sprinkler-controlled fires generally do not exceed 200°C. As such, hot gases spilling out of the openings near the booster are expected to be at a similar temperature or less. Using the Stefan-Boltzmann equation we can convert the temperature to a radiant flux to determine the impact of radiant heat on the fire brigade. Based on a temperature of 200°C, the radiant heat flux was estimated to be approximately 2.84 kW/m^2. According to the Fire Brigade Intervention Model V2.2 published by AFAC, fire brigade personnel are able to withstand 3 kW/m^2 for up to 10 minutes which is considered a sufficient amount of time to connect to the hydrant booster. As such it is considered that safe access to the hydrant booster would be provided in this scenario. The draft future standard AS2419.1-2017 supports the principle of relying on sprinklers to provide the protection, by removing the requirement for a fire resisting wall if the building is sprinkler protected.

In the unlikely event that the sprinkler system fails to operate, the fire brigade could access the booster under the protection of a charged hose connected to the pumping appliance's onboard water supply. A single hose with an extinguishing capacity of 16 MW at 10 L/s, could potentially extinguish the fire given the small size of the compartment adjoining the booster and the likely fire size. If the fire could not be extinguished, the fire hose would at least be capable of reducing the compartment temperatures in the vicinity of the openings such that the booster could be safely accessed.

5.9.5 Conclusion

Based on the qualitative assessment undertaken, it has been demonstrated that the attending fire brigade will be provided with safe access and protection to a degree necessary to facilitate fire brigade intervention. As such

Performance Requirements EP1.3, CP2 and EP2.2 are considered to be satisfied in terms of the BCA DtS departures assessed.

EP1.3	
A fire hydrant system must be provided to the degree necessary to facilitate the needs of the fire brigade appropriate to -	
a) fire-fighting operations; and	The assessment demonstrates that the fire brigade is expected to be provided with safe access to the pump room and the fire hydrant booster, to a degree necessary to facilitate fire brigade intervention.
b) the floor area of the building; and	The floor area of the building is relatively small and reduces the likely size of the fire.
c) the fire hazard.	The voluntary sprinkler system should reduce the fire hazard significantly when compared to a BCA DtS compliant design with no sprinklers.

CP2	
(a) A building must have elements which will, to the degree necessary, avoid the spread of fire -	
i) to exits; and	Not applicable to this assessment.
ii) between buildings; and	Not applicable to this assessment.
iii) in a building.	The sprinkler system provided throughout the building is expected to limit any fire spread.
(b) Avoidance of the spread of fire referred to in (a) must be appropriate to -	
i) the function or use of the building; and	Not applicable to this assessment.
ii) the fire load; and	The analysis considered fire scenarios based on typical fuel loads expected in the subject occupancy type.
iii) the potential fire intensity; and	The sprinkler system will limit the intensity of the fire and the compartment temperatures to less than 200°C.
iv) the fire hazard; and	The sprinkler system will reduce the fire hazard significantly when compared to a BCA DtS compliant design with no sprinklers.
v) the number of storeys in the building; and	Not applicable to this assessment. Fires on the Ground Floor only are expected to affect the items considered.
vi) its proximity to other property; and	Not applicable to this assessment.
vii) any active fire safety systems installed in the building; and	Sprinkler system to be provided in addition to BCA DtS requirements. The sprinkler system is expected to limit compartment temperatures significantly to facilitate fire brigade intervention.
viii) the size of any fire compartment; and	The floor area of the building is relatively small and reduces the likely size of the fire.

CP2	
ix) fire brigade intervention; and	Sprinkler system to be provided in addition to BCA DtS requirements. The sprinkler system is expected to limit compartment temperatures significantly to provide safe access to a degree necessary to facilitate fire brigade intervention.
x) other elements they support; and	Not applicable to this assessment.
xi) the evacuation time.	Not applicable to this assessment.

EP2.2	
(a) In the event of a fire in a building the conditions in any evacuation route must be maintained for the period of time occupants take to evacuate the part of the building so that -	
i) the temperature will not endanger human life; and	Sprinkler system is expected to reduce the temperatures to below 200°C near the booster. Given the external facilities for firefighting and the reduced temperatures, fire brigade access will be provided to the degree necessary.
ii) the level of visibility will enable the evacuation route to be determined; and	Given the external facilities for firefighting, fire brigade access will be provided to the degree necessary.
iii) he level of toxicity will not endanger human life.	Given the external facilities for firefighting, fire brigade access will be provided to the degree necessary.
(b) The period of time occupants take to evacuate referred to in (a) must be appropriate to -	
i) the number, mobility and other characteristics of the occupants; and	Not applicable to this assessment.
ii) the function or use of the building; and	Not applicable to this assessment.
iii) the travel distance and other characteristics of the building; and	Not applicable to this assessment.
iv) the fire load; and	Not applicable to this assessment.
v) the potential fire intensity; and	The sprinkler system will limit the intensity of the fire and the compartment temperatures to less than 200°C.
vi) the fire hazard; and	The sprinkler system will reduce the fire hazard significantly when compared to a BCA DtS compliant design with no sprinklers.
vii) any active fire safety systems installed in the building; and	Sprinkler system to be provided in addition to BCA DtS requirements. The sprinkler system is expected to limit compartment temperatures significantly to facilitate fire brigade intervention.
viii) fire brigade intervention.	Sprinkler system to be provided in addition to BCA DtS requirements. The sprinkler system is expected to limit compartment temperatures significantly to provide safe access to a degree necessary to facilitate fire brigade intervention.

Appendix 1 Referenced Information

A 1.1 Referenced Documentation

Table 26 : Summary of referenced documentation

[1]	ABCB 2016, *National Construction Code Series, Volume 1, Building Code of Australia 2014, Class 2 to Class 9 Buildings,* Australian Building Codes Board, Canberra.
[2]	ABCB 2005, International Fire Engineering Guidelines, 2005 Edition, Australian Building Codes Board, Canberra.
[3]	DBH 2012, C/VM2, Verification Method: Framework for Fire Safety Design, For New Zealand Building Code Clauses C1-C6 Protection from Fire, Department of Building and Housing, Wellington.
[4]	The hazard associated with removing smoke exhaust. Removal of mechanical smoke exhaust potentially result in compromised egress routes before all the occupants could safely egress.
[5]	PD7974-6 - 2004. “The application of fire safety engineering principles to fire safety design of buildings – Part 6: Human factors: Life safety strategies – Occupant evacuation, behaviour and condition (Sub-system 6)”, BSI British Standards.
[6]	Society of Fire Protection Engineers (SFPE) Handbook of Fire Protection Engineering 4th Edition, 2008.
[7]	CIBSE Guide E: Fire Safety Engineering, CIBSE, 2010.
[8]	NFPA 92B
[9]	Bennetts, I.D., and Thomas, I.R., Performance Design of Low-rise Sprinklered Shopping Centers for Fire Safety, Journal of Fire Protection Engineering, 2002.
[10]	Nystedt, F., Verifying Fire Safety Design in Sprinklered Buildings, Report 3150, Department of Fire Safety Engineering and Systems Safety Lund University, Sweden, 2011.
[11]	AS 1668.1 (2015)
[12]	AS 4100
[13]	AS 2218.1
[14]	AS 2293.1
[15]	AS 1670.1 (2015)
[16]	Hall, J 2010, ‘U.S experience with sprinkler and other automatic fire extinguishing equipment’, National Fire Protection Association, Quincy.
[17]	Ronchi, Enrico, et al. "Representation of the impact of smoke on agent walking speeds in evacuation models." Fire technology 49.2 (2013): 411-431.
[18]	Madrzykowski, D., The Reduction in Fire Hazard in Corridors and Areas Adjoining Corridor Provided with Sprinklers, Report NISTR 4631, NIST, US Department of Commerce.
[19]	Roytman, M. Ya., Principles of Fire Safety Standards for Building Construction, Construction Literature Publishing House, Moscow (1969). English translation (TT 71-580002) from National Technical Information Service (1975).
[20]	Development of Evaluation Methods for Fire Prevention/Resistance, Building Research Institute of Japan [in Japanese] (March 1997).

[21]	FBIM
[22]	Mawhinney, J.R., 1994, "Effects of automatic sprinkler protection on smoke control", National Research Council, Canada.
[23]	Marryatt, H. W., 1988, "A century of automatic sprinkler protection in Australia and New Zealand 1886-1986", Australian Fire Protection Association in co-operation with National Fire Protection Association International and National Fire Sprinklers Association Inc. U.S.A.

Appendix 2

Appendix 2 Evacuation Assessment

A 2.1 Introduction

The goal of this section is to successfully model the evacuation times for the building using the 3D pedestrian evacuation tool Pathfinder.

This analysis has been completed as part of the justification for Performance Solution 2.

The analysis documented herein details the evacuation period for the entire building, based on a considered fire scenario and the proposed active, passive fire safety systems, and the evacuation process adopted in the building.

The results of the analysis allow the determination of the Required Safe Egress Time (RSET).

A 2.1.1 Method of analysis used

Pathfinder is an emergency egress simulator that includes an integrated user interface and 3D results visualization. Pathfinder uses agent-based artificial intelligence. Each occupant has individual traits, goals, and perceptions. This allows groups of occupants to organize themselves into natural flow patterns. As a result, occupant motion looks smooth and realistic.

Rather than modelling occupants on a grid or as particles in a flow field, Pathfinder moves occupants in continuous 3D space. At each time step, every agent examines the surrounding environment and takes action based on their own conditions and goals.

A 2.2 Description of analysis

A 2.2.1 Methodology

An analysis of the total time to evacuate the building will be conducted. This analysis is based on the identification and quantification of the individual time elements, which contribute to the overall escape time. These elements include time periods related to the fire safety systems (e.g. time to detection and alarm), occupant pre-movement time (e.g. recognition and response time), and the time taken to actually travel out of the building. These are represented in the timeline shown in Figure 8.

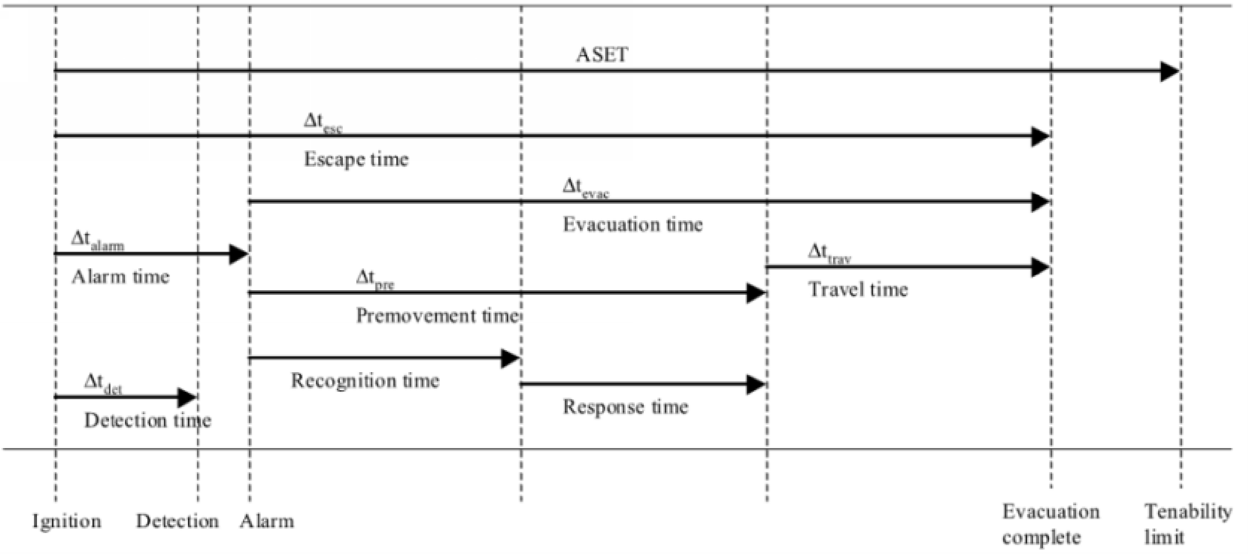


Figure 8 : Required Safe Egress Time (BS 7974-6)

The following evacuation scenarios have been undertaken to understand the evacuation from the building, reflecting a number of scenarios.

Table 27 : Discussion of egress scenarios analysed

Description	Discussion
Egress from the room of origin	In this scenario we are demonstrating safe egress from the room of origin, in that we will demonstrate tenable conditions are maintained for the duration of egress.
Egress from the building	This is the prescribed egress strategy for the building. In this scenario we are looking at two items; how quickly people get into the stair and when people get out of the building. This analysis demonstrates that the occupants are in a place of safety and outside the building before smoke spreads throughout the building and failure of any construction.

Appendix 2

Table 28 summarizes the components used in the evacuation analysis.

Table 28 : Summary of RSET components – Egress from the room of origin

Description	Value	Discussion
Time to Detection and Alarm	30 s *	Taken from the Fire and Smoke analysis (CFAST)
Time to Recognition and Response (Pre-movement time)	0 s *	Based on the small size of the rooms, occupants are expected to respond immediately after seeing a real fire.
Time to Travel and Queuing Time	11 s	Based on Pathfinder model
Full Evacuation Time	41 s	
Full Evacuation Time x 1.5 safety factor	62 s	
*The area of the modelled room does not exceed 54 m^2, and the room's layout is such that the occupants within would be made aware almost immediately of a fire. Therefore, a combined detection and response time of 30 seconds will be assumed. This is supported by the zone modelling in Appendix 4, which shows that at 30 seconds, the depth of the smoke layer under the ceiling is already 0.37 m deep and filled with dense smoke.		

Table 29 : Summary of RSET components – Egress from the building

Description	Value	Discussion
Time to Detection and Alarm	20 s	Taken from the Fire and Smoke analysis (CFAST)
Time to Recognition and Response (Pre-movement time)	60 s	Based on specific staff training and the SFPE Handbook [6].
Time to Travel and Queuing Time (stairway)	38 s	Based on Pathfinder model
Time to Travel and Queuing Time (outside the building)	62 s	Based on Pathfinder model
All occupants in exit stairs	118 s	
Full Building Evacuation Time	142 s	
All occupants in exit stairs x 1.5 SF	177 s	
Full Building Evacuation Time x 1.5 SF	213 s	

A 2.2.2 Extent of modelled space

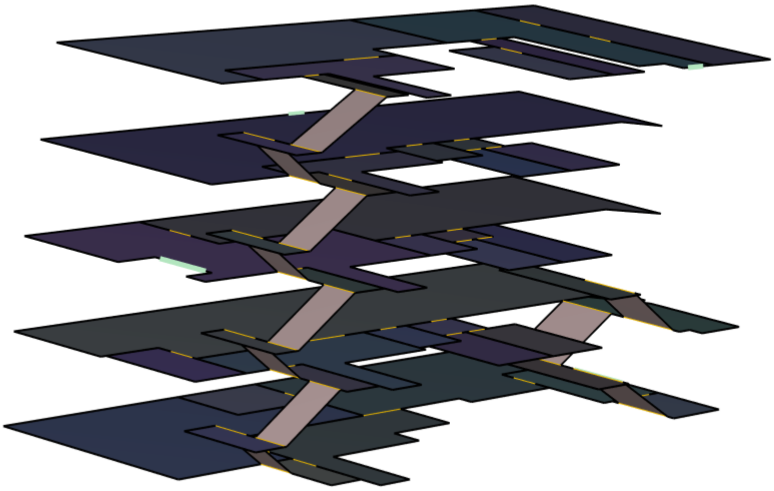


Figure 9: Bay 4 – Overall building

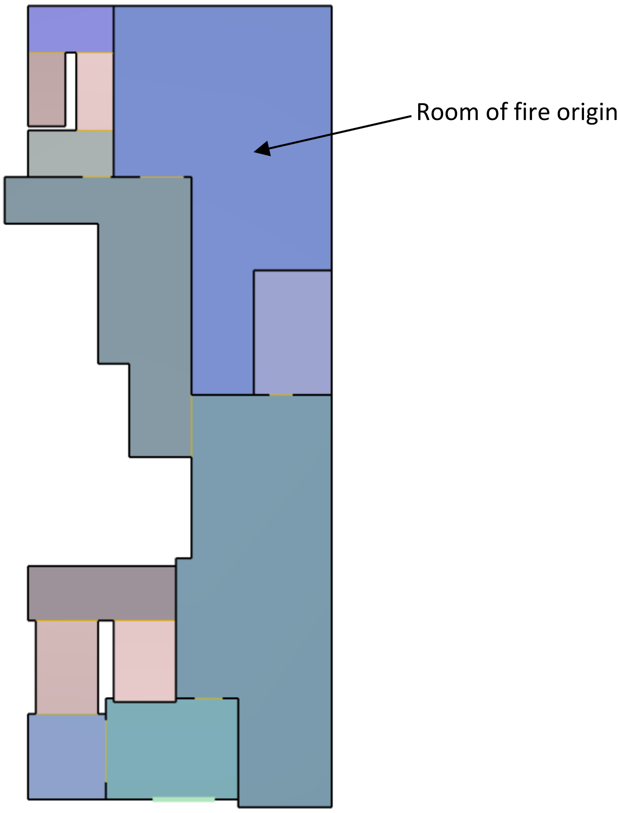


Figure 10: Bay 4 – Ground Level (subject room)

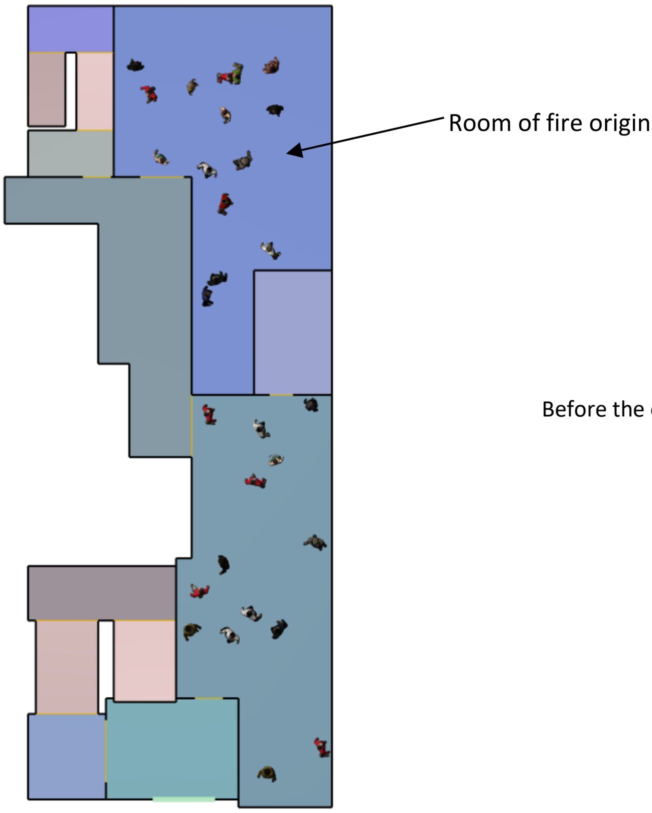
A 2.3 Results and discussion

A 2.3.1 Inputs

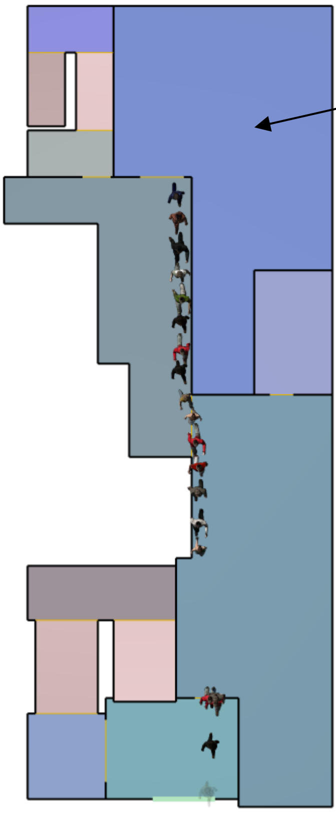
It is proposed to use the default SFPE settings in Pathfinder program for the analysis undertaken.

The populations have been modelled as per outlined in the BCA.

Table 30: Results of evacuation modelling – room of origin

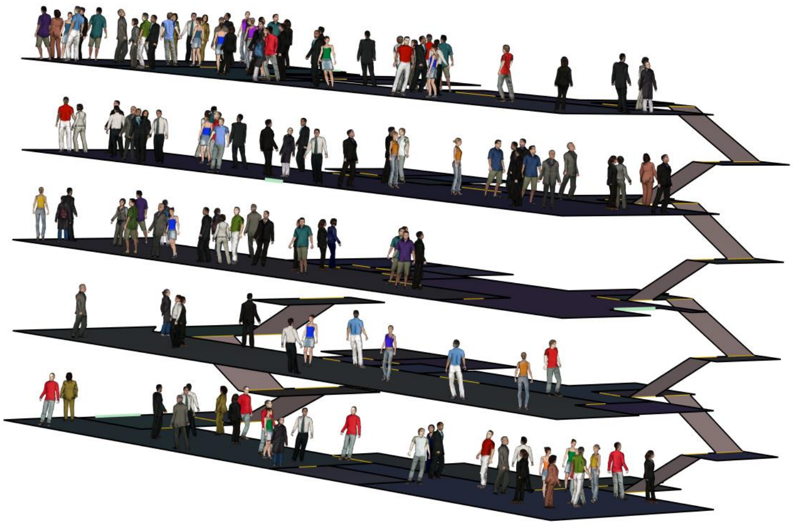
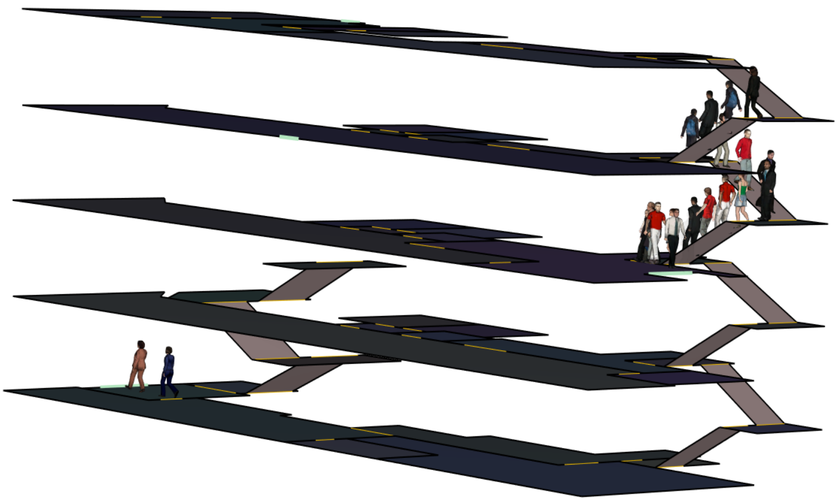
Time (sec)	Snapshot	
0 s		Before the evacuation begins
30 s	As above	Detection/alarm time & pre-movement time

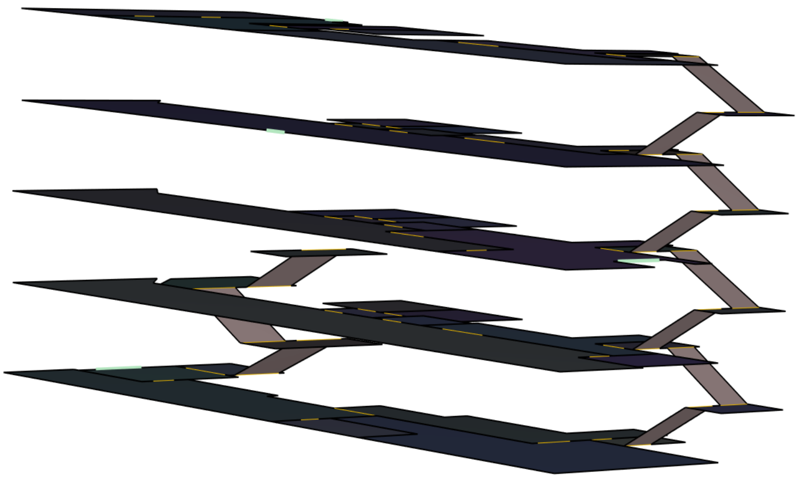
Appendix 2

Time (sec)	Snapshot
41 s	 Room of fire origin Occupants outside the room of fire origin 11 seconds after evacuation started

Appendix 2

Table 31: Results of evacuation modelling – entire building

Time (sec)	Snapshot	
0 s		Before the evacuation begins
80 s	As above	Detection/alarm time & pre-movement time
118 s		All occupants within fire exits 38 seconds after evacuation started

Time (sec)	Snapshot	
142 s		Full evacuation of the building 62 seconds after the evacuation started

A 2.4 Conclusion

A summary of the RSET result are detailed below.

Table 32: Summary of RSET

Description	RSET	RSET x 1.5
Egress from the room of origin	41 s	62 s
Occupants in exit stairs	118 s	177 s
Egress from the building	142 s	213 s

Appendix 3 CFAST Fire and Smoke Modelling

A 3.1 Introduction

This analysis has been completed as part of the justification for Performance Solution 2.

The analysis documented herein details the tenability conditions, temperature, time to detection based on a typical room, for a considered fire scenario and the proposed active and passive fire safety systems.

The results of the analysis allow the determination of the Available Safe Egress Time (ASET), through comparison with industry accepted tenability criteria.

In addition, the room temperature computed will be discussed in the context of fire separation between floors.

A 3.1.1 Method of analysis used

CFAST is a two-zone based fire simulation model, and may be used to calculate the evolving distribution of smoke, fire gases and temperature throughout compartments of a building during a fire. CFAST version 7.1.1 was developed by the National Institute of Standards and Technology (NIST) of the United States Department of Commerce.

CFAST was used to model the specified fire scenarios to determine the ASET.

A 3.1.2 Fire Scenarios

The following table outlines the simulated fire scenarios.

Table 33: Fire scenarios modelled

Scenario	Description	Commentary
1	Design Fire Scenario	A sprinkler controlled fire on the ground floor growing at a Medium growth rate until sprinkler activation. After sprinkler activation the fire size will remain constant.
2	Redundancy Fire Scenario	An uncontrolled fire on the ground floor growing at a Medium growth rate until flashover.

A 3.2 Description of analysis

This section discussed all the assumptions, inputs, acceptance criteria and methodology used as part of this analysis.

The simulation has been run for 900 seconds, which more than covers the evacuation time.

A 3.2.1 Extent of Modelled Space

The extent of the modelled space is shown below. The model was created to replicate the existing architectural design to a level of detail and accuracy which is considered to be acceptable.

The determine the worst case compartment, the following items were considered when selecting the location of the fire scenarios:

- Size – The smaller the compartment, the faster the temperature would rise and the faster hazardous conditions will occur.
- Level – Lower levels have the potential to affect more storeys above and hence would have the potential to affect more people.
- Presence of occupants – Small rooms such storage rooms and equipment rooms are not expected to be the worst case locations since these spaces are only accessed on an infrequent basis.

Appendix 3

Based on the considerations above, the following space on the Ground Floor was selected as the worst credible fire scenario location.

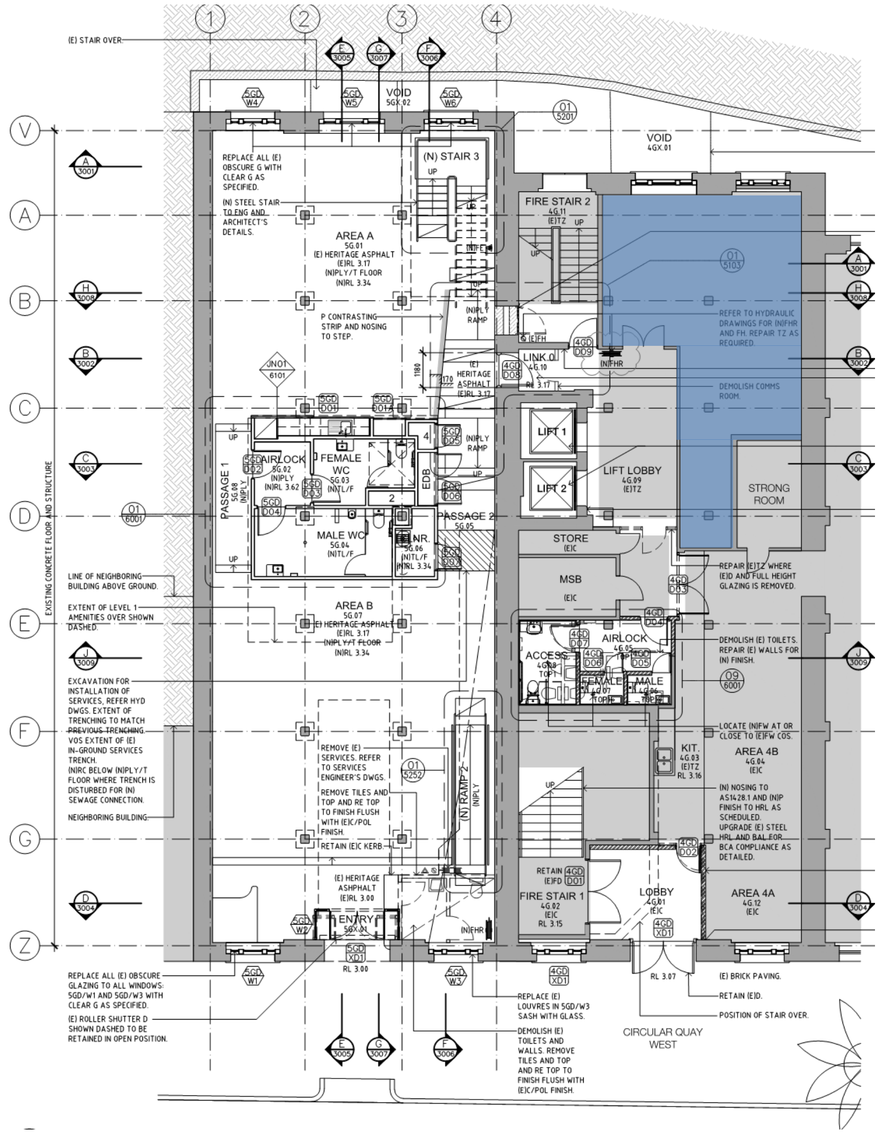


Figure 11: Ground Floor – Modelled compartment

The room was modelled as a simplified rectangular space with an equivalent floor area and volume as shown below.

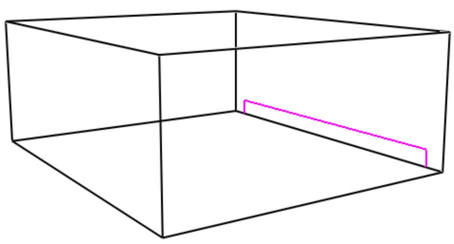


Figure 12: 3D perspective of modelled compartment

A 3.2.2 Design Fire

Design Fire Scenario

A sprinkler controlled fire on the ground floor growing at a Medium growth rate until sprinkler activation. From the CFAST results it was determined that the upper smoke layer within the compartment would reach the sprinkler activation temperature of 68°C at 110 seconds (refer to Figure 13). However, it was conservatively assumed that the sprinklers would have activated by the time the smoke layer reaches a temperature of 100°C at 140 seconds.

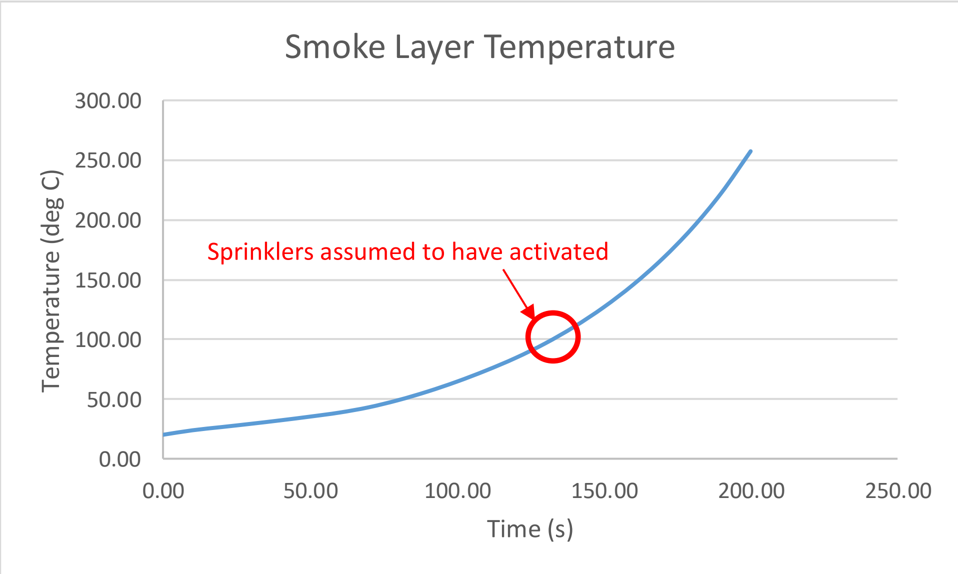


Figure 13: CFAST smoke layer temperature output for sprinkler activation modelling

The fire size at 140 seconds will be less than 300 kW if the fire grows at a Medium growth rate. Therefore, after sprinkler activation the fire size will remain constant at 300 kW. The heat release rate of the fire against time for the Design Fire Scenario is shown in Figure 14 below.

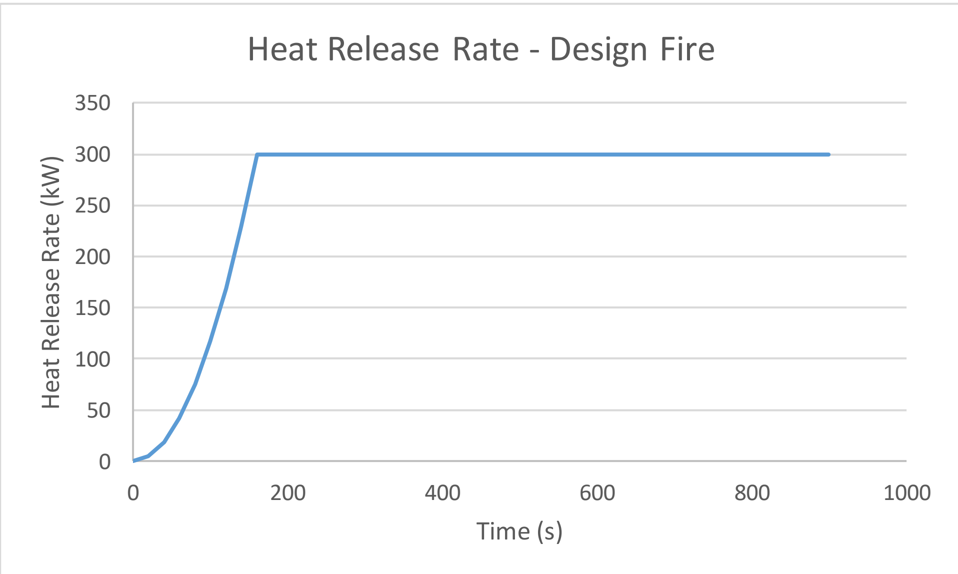


Figure 14: Heat Release Rate for the Design Fire Scenario

Redundancy Fire Scenario

An uncontrolled fire on the ground floor growing at a Medium growth rate until flashover. The heat release rate of the fire against time for the Design Fire Scenario is shown in Figure 15 below.

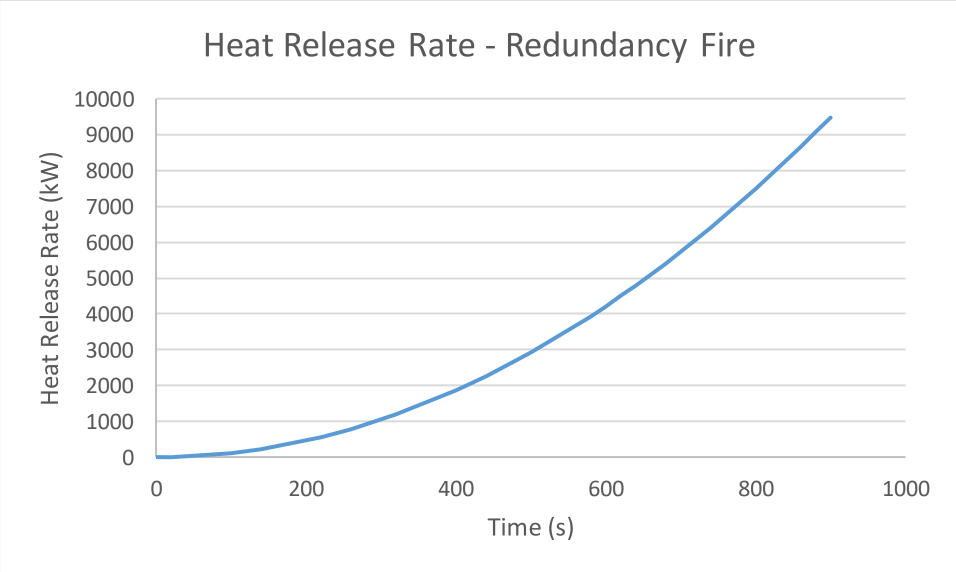


Figure 15: Heat Release Rate for the Redundancy Fire Scenario

Reaction Properties

The reaction used in the model was based on a mixture of materials such as timber, plastics and polyurethane foams. This is considered a reasonable scenario based on the usage of the building.

The average reaction values for the materials above, were taken from the SFPE Handbook [6] and are summarized in the table below.

Table 34: Reaction properties

Fire	Heat of Combustion	CO yield	Soot yield
Mixed materials	31 kJ/g	0.05	0.1

A 3.2.3 Tenability and Failure Criteria

The following tenability criteria will allow the determination of the ASET from the simulated model.

Table 35 : Occupant tenability and failure criteria

Criteria		Reference
Convective heat	Temperature > 120 °C when smoke layer is below 2.0 m	BS 7974: PD 6 [19]
Radiant heat exposure	Radiant flux > 2.5 kW/m^2 at 2.0 m, or smoke layer temperature > 200 °C when smoke layer is at or above 2.0 m	
Visibility	Visibility >5 m when smoke layer is below a height of 2.0 m for queueing Visibility >10 m when smoke layer is below a height of 2.0 m for large spaces	

Appendix 3

Criteria		Reference
Structural Stability	Timber Floors - 300°C based on the charring characteristics of timber. (SFPE Handbook 2002) Concrete / steel plates – Expected to be greater than 300°C, however a 300°C failure criterion for fire spread will be assumed as well for conservatism.	
Smoke beyond the room of origin.	Temperature > 300 °C is considered to be a reasonable criteria based on the construction provided (timber floor / ceiling structures). (SFPE Handbook 2002)	

Structural Stability - Fire Performance of Materials – Timber

Based on the information received it is noted that the construction of the building contains the following elements:

- Timber floors supported by timber beams and columns

The insulating properties of timber can provide built-in fire resistance. Large timber members burn slowly, and form char on the surface.

The un-burnt timber section retains most if not all their strength during a fire. Because timber is dimensionally stable under fire conditions, failure will not occur until the cross section has been reduced to the point at which the remaining structural section is no longer adequate for the service conditions. This generally allows fire fighters to operate safely for some time in or around a burning building of heavy timber construction. Solid timber during exposure to fire, has a slow and predictable charring rate, dependant on the timber species.

When a fire is brought under control before major damage occurs, heavy timber members will frequently still be usable, subject to cosmetic repairs and confirmation of their structural integrity. Light timber frame construction can also be protected to provide a high degree of fire performance using fire resistant lining materials. Because wood burns, many people wrongly assume that timber buildings have poor behaviour in fires.

However, timber buildings can be designed with excellent fire safety for the occupants and sufficient fire resistance to inhibit spread of fire or structural failure. Large sized timber members have the inherent ability to provide fire resistance because of the unique charring properties of wood.

When wood is exposed to high temperatures it will decompose to provide an insulating layer of char that retards further degradation of the wood. The rate of char is initially fast but as the char increases it slows as this insulating layer grows. The rate at which timber chars varies between species and is predominately dependent on density and moisture content. The predictability of timber charring is used by building regulators to develop Fire Resistance Levels for building elements like large cross-section timber columns and beams. The Australian Standard AS 1720.4 Timber Structures: Fire resistance of structural timber members provides a method for calculating fire resistance levels for solid timber.

Large cross-section timber is able to carry load during a fire event as the char occurs on the outside of the element and only slowly reduces the effective cross section of the timber. The insulating qualities of timber mean that although the temperature at the char layer may be 300 °C, the temperature of the inner wood is considerably lower. The remaining uncharred cross-sectional area of a large wood member remains at a low temperature and can continue to carry a load.

Appendix 3

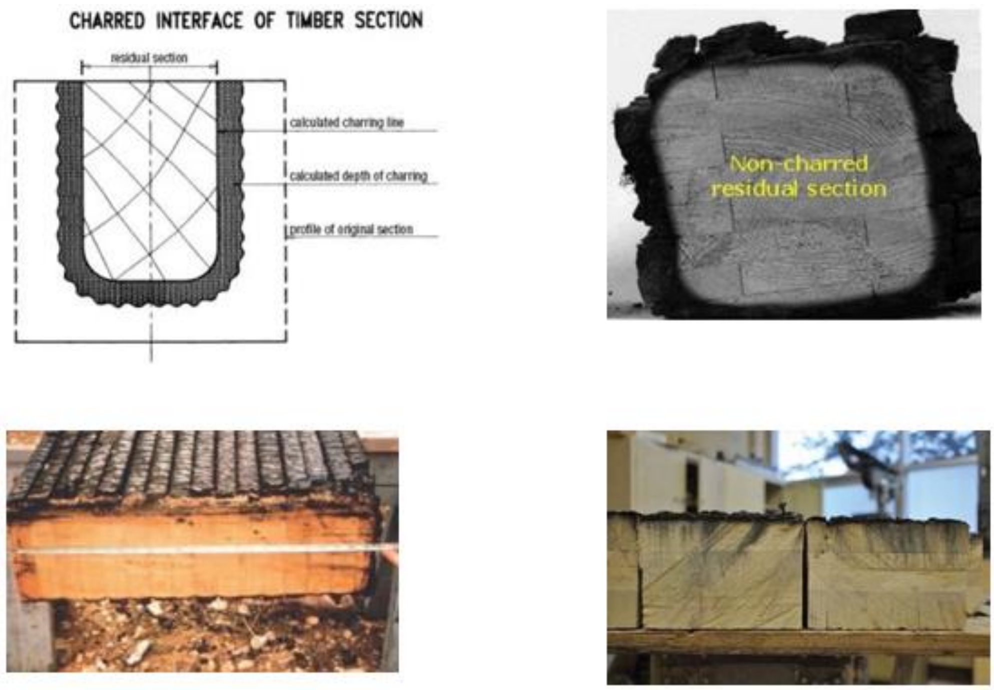


Figure 16: Charring of Timber Sections

The char which forms on timber during a fire is an effective insulator which protects the inner section of timber from the effects of heat. At a distance of 20 mm from the edge of the char, the internal temperature of the wood will only be about 80 °C. At this temperature, the beam will retain 80 % of its tension and compression strength, and 95 % of its stiffness (modulus of elasticity). This contrasts with other structural materials such as unprotected steel I-beams.

Comparative fire tests of timber and steel showed that a steel I-beam deflected 900 mm after 30 minutes' exposure to a standard fire, while glue laminated timber beam of the same load-bearing capacity deflected only 60 mm.

Wood is a complex mixture of natural polymers. The most important constituents being cellulose, hemicellulose and lignin which are present in the approximate proportions of 50, 25 and 25 %. The actual proportions may vary depending on the wood species. When wood is heated these constituents decompose at different temperatures to release combustible volatiles. When wood burns, about 15-25 % will remain in the form of a 'char' and most of this is from the lignin content (refer to Table 36).

When the fire exposure is intense the boundary transition from the charred area to the remaining heated wood is quite distinct. A commonly accepted charring temperature of wood is about 300 °C.

For a given fire severity, an average charring rate (mm/min) can be used to predict the amount of charred material as a function of time, and this is commonly the basis of calculating the fire resistance of heavy timber structural members.

Table 36: Decomposition temperature of wood constituents

Constituent	Decomposition Temperature
Hemicellulose	200 – 260 °C
Cellulose	240 – 350 °C

Appendix 3

Constituent	Decomposition Temperature
Lignin	280 – 500 ^{o}C

In light timber framed structures, the design and use of appropriate lining materials (i.e. plasterboards) can provide timber framing with excellent fire resistance by protecting the wood from the direct impact of the fire.

The use of large solid timber panels in office buildings is favourable in case of fire, as the risk of fire spread through void cavities is reduced in comparison to light timber frame constructions.

Combustible building materials like timber burn on their surface, release energy and thus contribute to fire propagation and the development of smoke in case of fire. The main precondition for the use of wood for buildings is adequate fire safety. Fire safety is an important contribution to feeling comfortable and an important criterion for the choice of material in particular for office buildings.

As stated previously, timber is a combustible material and thus differs from most other commonly used structural building materials. When sufficient heat is applied to wood, a process of thermal degradation (pyrolysis) takes place producing combustible gases, accompanied by a loss in mass. A charred layer is then formed on the fire exposed surfaces and the char layer grows in thickness as the fire progresses, reducing the cross-sectional dimensions of the timber member. The char layer is a good insulator and protects the remaining uncharred residual cross-section against heat.

After the charred layers have fallen off, an increased charring is expected due to the increased fire temperature. This phenomenon is similar to the increased charring observed for protected timber surfaces after failure of the fire protective cladding. The position of the panel (horizontal for slabs, vertical for walls), the thickness of the layers as well as the behaviour of the bonding adhesive at high temperature can influence the falling of the charred layers and thus play an important role in the evaluation of timber elements.

Based on the above information, it has been conservative to assume that structural failure occurs at 300°C.

Appendix 3

A 3.3 Summary of Smoke Calculations

Table 37: Scenario and corresponding parameters

Scenario/Parameter	Design Fire Scenario	Redundancy Fire Scenario
Fire Data		
Maximum HRR	0.3 MW	Uncontrolled
Fire Growth Rate	0.01172 kJ/s^3	0.01172 kJ/s^3
Smoke detector activation	0.097 1/m	0.097 1/m
HRR per unit area	1000 kW/m^2	1000 kW/m^2
Radiant Loss Fraction	0.35	0.35
Room Geometry		
Floor to ceiling height	3.0 m	3.0 m
Area	54 m^2	54 m^2
Ventilation Data		
Area of opening	2.8 m^2 - Provided at low level	2.8 m^2 - Provided at low level
Height of opening	0.4 m	0.4 m
Number of ventilation points	1	1

Appendix 3

A 3.4 Results

The CFAST zone modelling results for both fire scenarios are shown below.

A 3.4.1 Design Fire Scenario

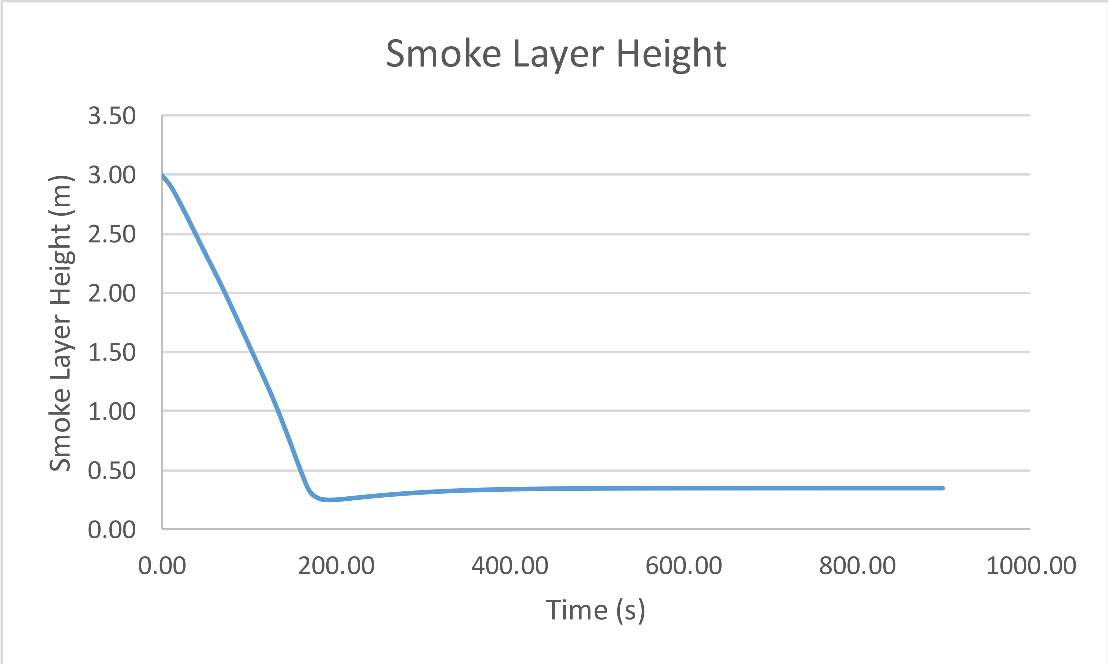


Figure 17: Smoke Layer height

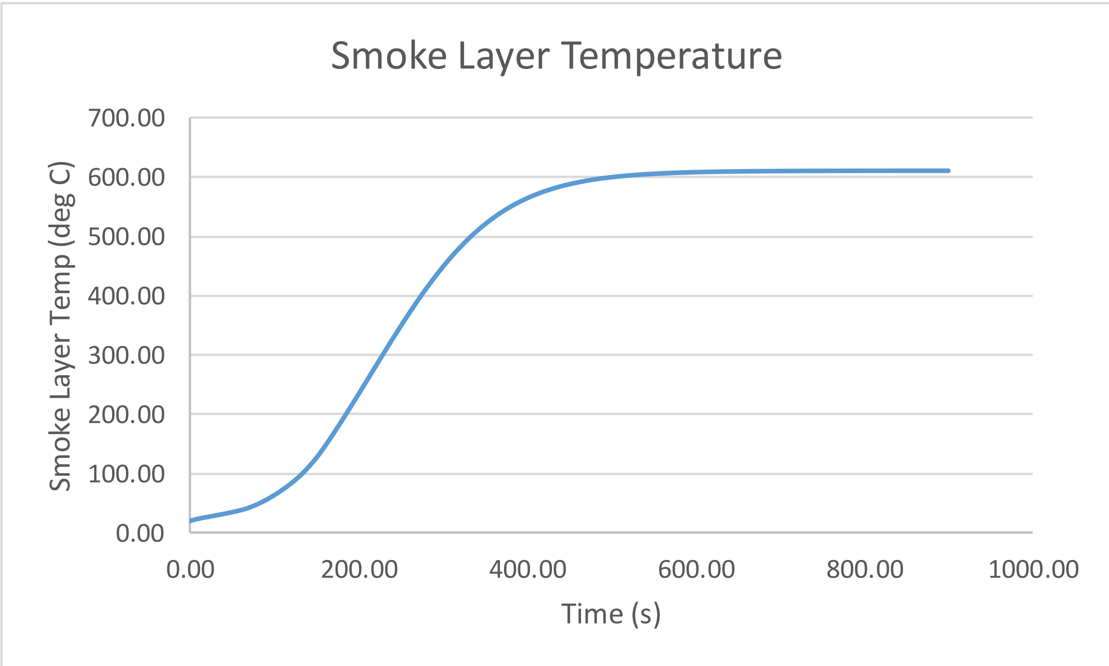


Figure 18: Smoke Layer Temperature

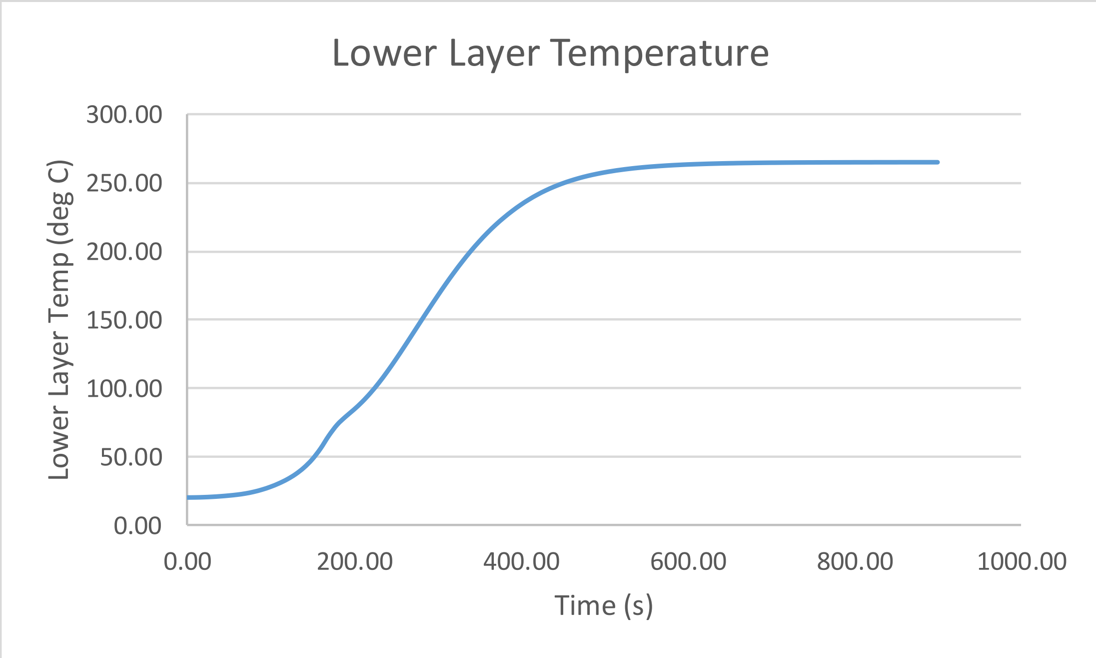


Figure 19: Lower Layer Temperature

As detailed in Figure 17, the smoke layer height falls below 2 m at approximately 70 seconds.

Figure 18 & Figure 19, illustrate the increase in temperature of the upper smoke layer and the lower layer respectively. It can be seen that the smoke layer reaches a temperature of 120°C (failure criteria for occupants) at approximately 150 seconds and 300°C (failure criteria for compartment separation, i.e. timber floor / ceiling) at approximately 230 seconds.

A 3.4.2 Redundancy Fire Scenario

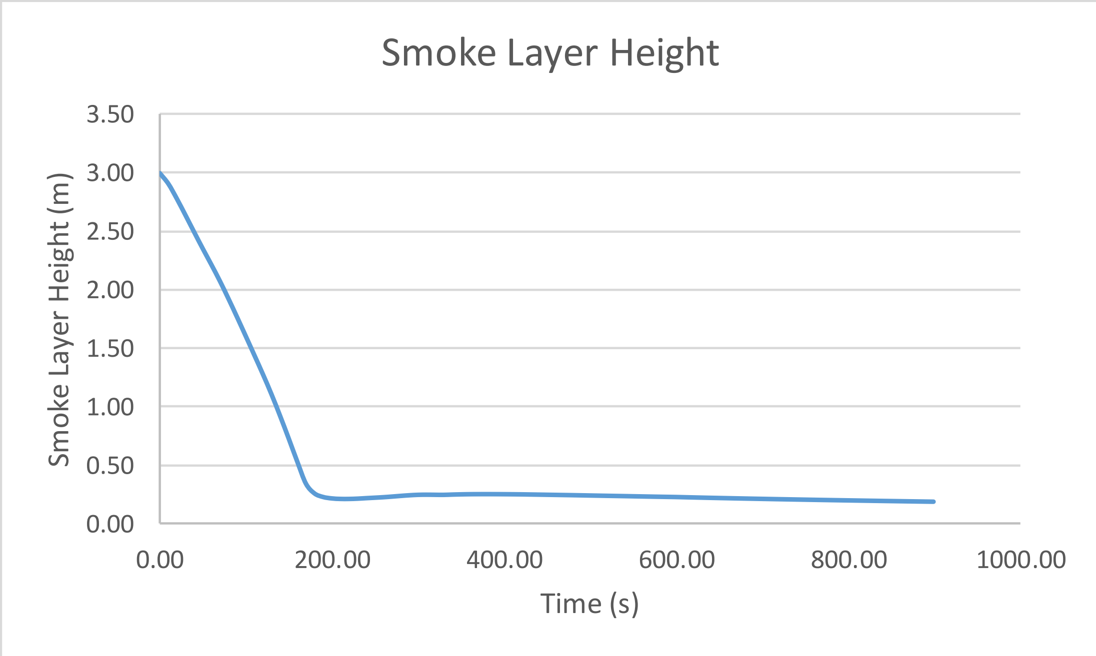


Figure 20: Smoke Layer height

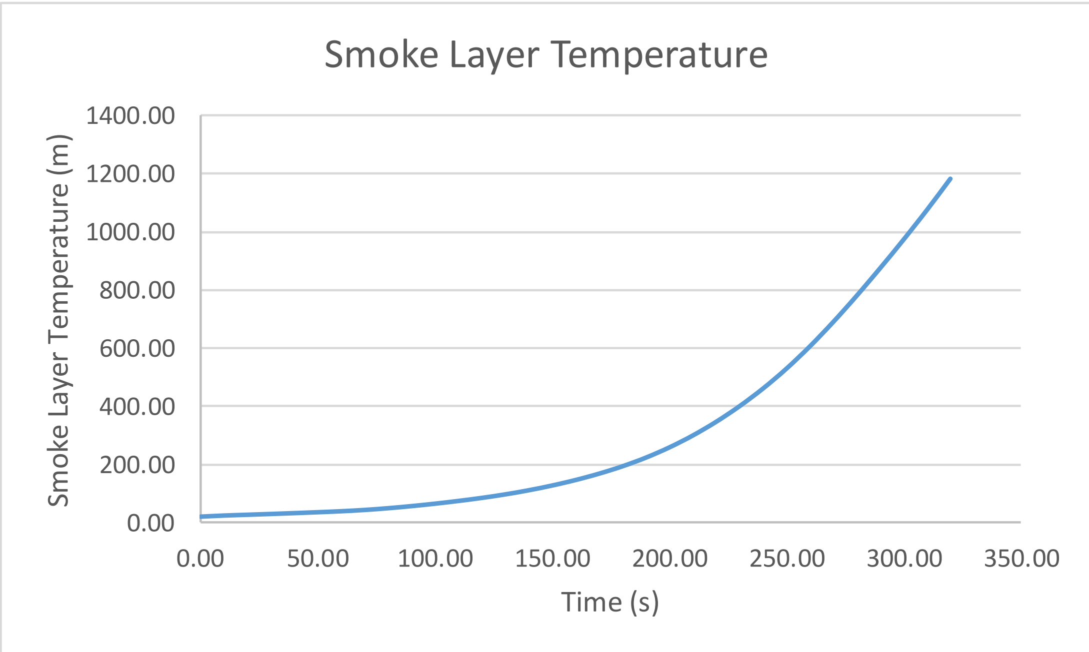


Figure 21: Smoke Layer Temperature

Appendix 3

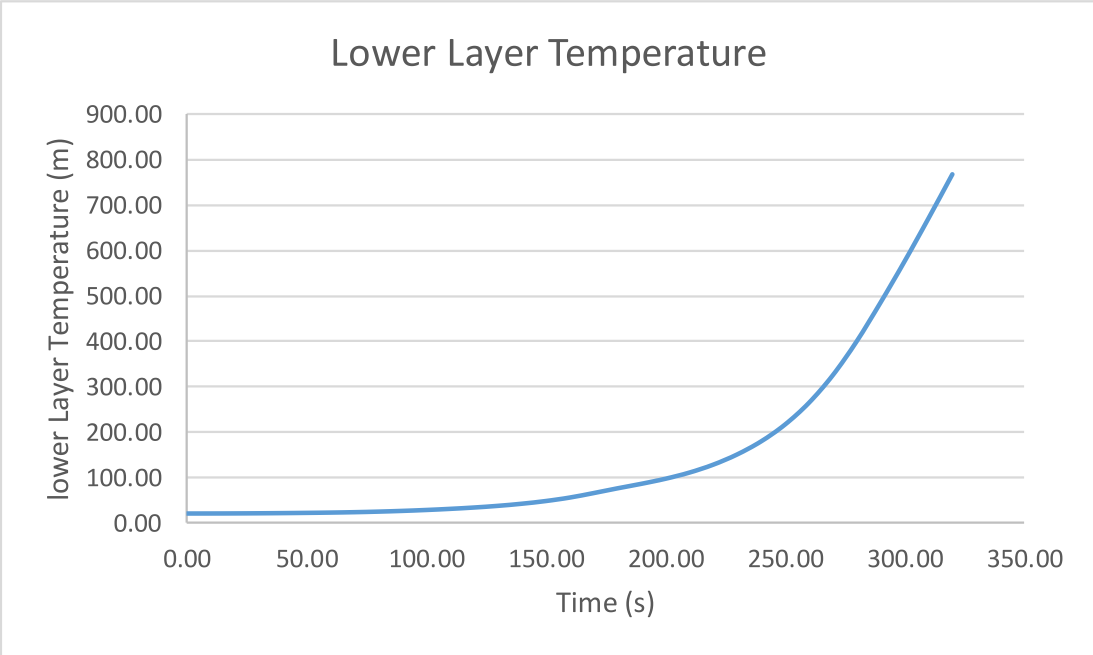


Figure 22: Lower Layer Temperature

As detailed in Figure 20, the smoke layer height falls below 2 m at approximately 70 seconds.

Figure 21 & Figure 22, illustrate the increase in temperature of the upper smoke layer and the lower layer respectively. It can be seen that the smoke layer reaches a temperature of 120°C (failure criteria for occupants) at approximately 150 seconds and 300°C (failure criteria for compartment separation, i.e. timber floor / ceiling) at approximately 210 seconds.

A 3.5 Conclusion

A summary of the results is detailed in the table below.

Table 38: Design Fire Scenario - Summary of ASET and Events

Criteria	Criteria	Time	Discussion
Convective heat	120 °C	150 s	At this point everyone has left the room or fire origin.
Radiant	200 °C	190 s	At this point everyone has left the room or fire origin.
Visibility	10m	70 s	At this point everyone has left the room or fire origin.
Smoke Layer	2m	70 s	At this point everyone has left the room of fire origin.
Structural Stability Spread of fire to other compartments	300 °C	230 s	At this point everyone has left the building.

Appendix 3

Table 39: Redundancy Fire Scenario - Summary of ASET and Events

Criteria	Criteria	Time	Discussion
Convective heat	120 °C	150 s	At this point everyone has left the room or fire origin.
Radiant	200 °C	180 s	At this point everyone has left the room or fire origin.
Visibility	10m	70 s	At this point everyone has left the room or fire origin.
Smoke Layer	2m	70 s	At this point everyone has left the room of fire origin.
Structural Stability Spread of fire to other compartments	300 °C	210 s	At this point everyone has left the building.

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