Olsson
Fire & Risk
CONSULTING ENGINEERS

Resource Co.
Wetherill Park, NSW, 2164

Fire Engineering Report

Revision: FER 2.0

5 October 2017

S15332

We
listen,
explore,
create,
deliver.

Olsson
Fire & Risk
CONSULTING ENGINEERS

Prepared for:	Ahrens Group Pty Ltd
Project Location:	35-37 Frank Street, Wetherill Park, New South Wales, 2164
Prepared by:	Olsson Fire & Risk Pty Ltd Suite 4.03 | 56 Clarence Street Sydney NSW 2000
Project No:	S15332
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Quality Management

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Author	**Colin Thomson** **Sam Alshroof**	**Colin Thomson** **Sam Alshroof**	**Colin Thomson** **Sam Alshroof**	**Colin Thomson**
Technical Review	**Trent De Maria**	**Trent De Maria**	**Trent De Maria**	**Trent De Maria**
QA and Authorisation	**Carl Voss**	**Carl Voss** C10: BPB1843	**Carl Voss** C10: BPB1843	**Carl Voss** C10: BPB1843
Signature				

Executive Summary

Olsson Fire & Risk Pty Ltd has been appointed by Ahrens Group Pty Ltd. Our task is to undertake a fire engineering assessment for the development located at 35-37 Frank Street, Wetherill Park, New South Wales, 2164.

The objective of this Fire Engineering Report is to address any identified departures from the Building Code of Australia (BCA) Deemed to Satisfy (DtS) Provisions within the development and to present a solution for each demonstrating compliance with the relevant BCA Performance Requirements.

The following variations to the BCA DtS Provisions have been identified by the Principal Certifying Authority and are addressed in this report:

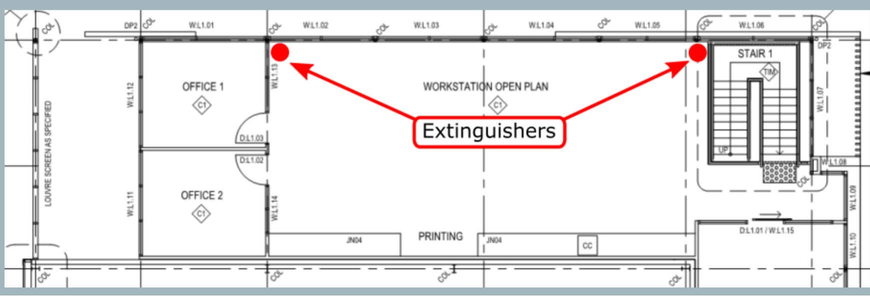
Table 1: Summary of DtS Non-Compliances

Sol.	Description of DtS non-compliance	DtS Clause	Performance Requirement	IFEG Sub-systems
1	The vehicular perimeter access requires passing through gated entry points, as well as travelling over a transmission line easement for one part of the access.	C2.4	CP9	F
2	Travel distances within the manufacturing building are expected to be in excess of DtS compliant values, to the extent of: ▪ Up to 30 m to a point of choice in lieu of 20 m. ▪ Up to 60 m to an exit in lieu of 40 m. ▪ Up to 80 m between exits in lieu of 60 m. As well, exit signage in the manufacturing building may be installed up to 4 m above the floor level, in excess of the recommended 2.7 m height from AS2293.1.	D1.4, D1.5, E4.8	DP4, EP2.2, EP4.2	B, D, E, F
3	Travel distances within on the first floor of the office is extended up to 25 m to a single exit, in lieu of 20 m.	D1.4	DP4, EP2.2	E, F
4	The sliding doors to the office areas shall not meet the requirement of automatically failing open upon alarm or power failure.	D2.19	DP2	E, F

On the basis of the analysis undertaken within the body of this report, the following fire safety measures detailed in Table 2 are required as part of the fire design.

Table 2: Required Fire Safety Features

Fire Safety Measure	Description
General	If not specifically mentioned the following fire safety measures are to be provided in accordance with the Deemed-to-Satisfy provisions. This includes the provision of: ▪ Automatic Fire sprinkler system (AS 2118.1-1999) – Manufacturing building only ▪ Automatic signalling equipment ▪ Building Occupant Warning System (1670.1-2015) – Manufacturing building only ▪ Emergency lighting and exit signs (AS 2293.1-2005) ▪ Fire hose reels (AS 2441-2005) ▪ Fire Hydrant System (AS 2419.1-2005)

Fire Safety Measure	Description
	▪ Portable fire extinguisher (AS 2444-2001) ▪ Statutory signage
Construction Requirements	<u>Fire Resistance, Stability and Hazard Properties</u> In accordance with Part C of the BCA.
Perimeter Vehicular Access	Perimeter vehicular access to the site is to be provided in accordance with BCA Clause C2.4, with the exception that gates at the entry to the site may be closed and passage of roadway will be over the transmission line easement. The following additional requirements are made: ▪ Gates and security checkpoints in the emergency vehicle travel path are to be secured with a loose chain and 003 type padlock or be provided with locking devices that can be unlocked by key (i.e. provided to the two nearest local fire stations) and be manually released or operated onsite (i.e. manual override). ▪ Hydrant valves are to be located clear of the transmission line easement. ▪ Any hydrant valves located within 10 m of the transmission line easement will have signage posted to be clearly visible to fire brigade personnel before operation of the hydrants. This sign will be similar to the sign below which is in accordance with WorkCover Code of Practice for Overhead Power Lines. This sign, or one similar, shall also be posted at each entry to the site.  ▪ The location of the transmission line easement is to be included on each block plan throughout the site (i.e. at the FIP, hydrant booster, and pump room).
Fire hydrant system	A fire hydrant system shall be provided in accordance with BCA Clause E1.3 and AS 2419.1, with the additional FRNSW Special hazard requirement that the system shall be capable of supplying a minimum 40 L/s for at least 4 hours.
Fire hose reels	Fire hose reels shall be provided in accordance with BCA Clause E1.4 and AS 2441.
Portable fire extinguishers	Portable fire extinguishers will be provided in accordance with BCA Clause E1.6 and AS2444. As per Section 5.3 of this report – two additional, multi-purpose Type ABE dry powder fire extinguishers (minimum 2.5 kg size) shall be provided to the first floor office area, in approximately the locations depicted below. 

Fire Safety Measure	Description
Fire sprinkler systems	A fire sprinkler system in accordance with AS2118.1 and BCA Clause E1.5 shall be provided throughout the manufacturing building. The response time index of the sprinklers shall not be greater than 50 $m^{½}s^{½}$.
Building Occupant Warning System (BOWS)	A building occupant warning system in accordance with AS1670.1 shall be provided throughout the manufacturing building. Activation of the fire sprinkler system shall activate the building occupant warning system. Emergency manual call points in accordance with AS1670.1 shall be provided within the manufacturing building. The manual call points shall be white in colour and designed in accordance with the 'Emergency Warning' functionality of Clause 3.15 of AS1670.1 to activate the building occupant warning system only. These manual call points shall be distributed to the exits from the manufacturing building.
Emergency lighting and **e**xit signs	Emergency lighting and exit signage shall be provided in accordance with BCA Clause E4.2 and E4.5 respectively, and AS2293.1, with the exception that exit sign heights may be up to 4 m above the ground level in the manufacturing building. The extended height signs are to be 'Jumbo' signs.
Management in use	An emergency management plan in accordance with AS 3745 shall be provided.
Maintenance	A maintenance program shall be developed with all essential safety maintained in accordance with AS1851 and AS2293.2.

FRNSW Special Hazard Requirements	In addressing the Special Hazard provision of E1.10 and E2.3 as part of the Development Consent, the following fire safety measures are required by FRNSW (See Section 4.4 and Appendix F):
	▪ The stockpiles within the RAW and PEF areas shall be separated as follows:
	    ▪ The RAW area shall be divided into at least three (3) stockpile bays, of a maximum size of 1,000 m^3.
	    ▪ The PEF area shall be divided into at least two (2) stockpile bays, of a maximum size of 825 m^3.
	    ▪ Each stockpile shall be separated from one another by 120 minute fire rated bays of masonry construction. The separating construction shall be at least 2 m high.
	    ▪ The site shall maintain at least two (2) front end loaders on-site with bucket capacities of 4.9 m^3 each.
	▪ The site shall be capable of retaining contaminated fire water flowing for up to 90 minutes, equating to approximately 470,000 L, within the footprint of the building.
	▪ A ridge vent, running the length of the building at the highest point, shall be provided to meet the following requirements:
	    ▪ Minimum throat open diameter of 1,200 mm
	    ▪ Protected from wind via shielding for the length of the ridge vent, such that any inlet/discharge is not exposed to the horizontal movement of air or wind external to the building.
	    ▪ The ridge vent design shall meet or exceed the design exhaust capacity noted in Section D.6, Table 27.
	▪ Make-up air is to be provided by the dado-wall setback from the steel-clad wall by at least 500 mm, around the perimeter of the building.

Fire Safety Measure	Description
	▪ The roller shutter for the PEF storage area shall open upon sprinkler activation to provide additional make-up air and venting capabilities to the PEF area. Cabling to the roller shutters shall be in accordance with AS 1668.1.

Contents

1 Introduction

1.1 Appointment

Olsson Fire & Risk Pty Ltd has been appointed by Ahrens Group Pty Ltd. Our task is to undertake a fire engineering assessment for the development located at 35-37 Frank Street, Wetherill Park, New South Wales, 2164.

1.2 Applicable Legislation

The primary legislation applicable to the development is the BCA 2016: Building Code of Australia.[1] The BCA provides a set of prescriptive requirements, *Deemed-to-Satisfy* (DtS) Provisions, that provides a deemed acceptable level of safety and assumed compliance with the BCA Performance Requirements. Variations from the BCA DtS Provisions may be addressed as proposed Performance Solutions if they comply with the BCA Performance Requirements.

The assessment of a Performance Solution can be undertaken using a variety of methods. These are defined in BCA Clause A0.5. One or more, or a combination of these methods are adopted to determine whether the proposed Performance Solution complies with the BCA Performance Requirements. The relevant BCA Performance Requirements are determined in accordance with BCA Clause A0.7. Compliance with BCA Performance Requirements is undertaken in accordance with BCA Clause A0.2.

1.3 Regulatory Framework

The following New South Wales Legislation is applicable:

- NSW Environmental Planning and Assessment Act, 1979 and subsequent amendments
- NSW Environmental Planning and Assessment Regulation, 2000 and subsequent amendments

This document has been prepared by Olsson Fire & Risk to meet the legislative requirements of the NSW Environmental Planning and Assessment Regulations 2000 to support the application for a Construction Certificate (CC). Steve Watson of Steve Watson & Partners is the Principal Certifying Authority (PCA) for purposes of assessing an application for the CC.

1.4 Fire Engineering Process

In accordance with the International Fire Engineering Guidelines (IFEG), the fire engineer should undertake a Fire Engineering Brief (FEB) process for every project carried out. The Fire Engineering Brief process is required to include the objectives, proposed trial designs, methods of analysis and acceptance criteria for any proposed Performance Solutions. This process may be documented in an individual document, or combined in the Fire Engineering Report.

The Fire Engineering Report (FER) contains all the relevant design calculations and justifications to demonstrate that the proposed Performance Solutions comply with the relevant BCA Performance Requirements. Stakeholder approval of the FER is to be gained before submission to the PCA for their assessment of compliance to the BCA Performance Requirements.

The FEB process has identified Category 2 Fire Safety Provisions (as defined by the EP&A Regulation 2000) and so requires a referral to the fire brigade under Clause 144 of the Regulation Therefore, the Fire Authority has been identified as a stakeholder in the FEB/FER process, as confirmed by the PCA. A Fire Engineering Brief Questionnaire was submitted to the Fire Authority (FRNSW) on 23 December 2016, with responses by FRNSW received 07 February 2017. These responses have been incorporated in this document in Appendix C.

Further, the Development Conditions identified the building as subject to ‘Special Hazard’ provisions of the BCA, and that FRNSW was an approval authority. These requirements are detailed in Section 4.4, Appendix D and Appendix F.

[1] See Section 1.7 for a list of references

1.5 Scope and Objectives

The objective of the Fire Engineering process is to recognise variations from the DtS Provisions and to present a way forward for resolution of each, and to demonstrate compliance with the relevant BCA Performance Requirements. All design solutions are subject to formal approval by the relevant regulatory authorities.

In order to provide a robust fire engineering design that meets the BCA Performance Requirements, it is important that all stakeholders agree to the fire engineering design principles before the analysis is carried out and the design is finalised. Key features of this report are to be reviewed and agreed to by the stakeholders, including the assumptions, design fires, occupant characteristics, proposed fire and egress modelling scenarios (where applicable), methods of analysis and the proposed overall design philosophy.

1.6 Stakeholders and Documentation

The relevant stakeholders in the design of this development are listed in Table 3.

Table 3: Relevant Stakeholders

Name	Organisation	Role
Laurie Andrews Giuseppe Gigliotti	Ahrens Group Pty Ltd	Client
Matt Bell	Bell Architecture	Architect
Steve Watson	Steve Watson & Partners	Principal Certifying Authority
Andrew Rys Joshua Hawke	Steve Watson & Partners	BCA Consultants
Chris Brown Ben Hamilton Daire Fleming Mark Castelli	Fire & Rescue NSW	Fire Brigade Referral
Colin Thomson Trent De Maria Carl Voss	Olsson Fire & Risk Pty Ltd	Fire Engineering

The relevant documents and drawings assessed as part of this report are listed in Table 4.

Table 4: Relevant design team documentation

Ref	Name	Organisation	Date	Revision
WD-1001 – WD-9101	Architectural Plans – March 2017 Issue	Bell Architecture	28/02/2017	T1
2016/1668	BCA Assessment report	Steve Watson & Partners	22/11/2016	R1.0
FRN16/617 (12491)	Fire Engineering Brief Questionnaire	Olsson Fire & Risk and Fire and Rescue NSW	07/02/2017	V02
SSD 7256	Development Consent	Department of Planning and Environment, NSW Government	10/04/2017	15/13400

1.7 References

Abbreviation in square brackets is how item is referred to throughout this report.

1.7.1 Australian Legislation and Referenced Documents

[BCA] *National Construction Code Series Volume 1: Class 2 to 9 buildings – Building Code of Australia 2016, Australian Building Codes Board. National Construction Code Series Volume 1 Appendices: Variations and Additions – Building Code of Australia 2016, Australian Building Codes Board.*

[EP&A Act] *NSW Environmental Planning and Assessment Act 1979*.

[EP&A Regs] *NSW Environmental Planning and Assessment Regulation 2000* and subsequent amendments.

1.7.2 Texts and Guidance Documents

[AFAC] *Australasian Fire and Emergency Services Fire Brigade Intervention Model*, Australasian Fire Authorities Council.

[BCA Guide] *Guide to the Building Code of Australia, Australian Building Codes Board, 2016.*

[Bukowski] *Estimates of the Operational Reliability of Fire Protection Systems,* Bukowski, Budnick and Schemel, International Conference on Fire Research and Engineering, 1999.

[CIBSE] *CIBSE Guide E: Fire Safety Engineering,* London, ISBN: 9781906846138, 2010.

[Fisher] *Processed Engineered Fuels Derived from paper and plastics – Techno-economic factors and regulatory issues in a competitive market,* Fisher, M., Ohlsson, O., Singhania, A., Sosa, J., 5th Annual North American Waste-to-Energy Conference, 1997.

[Fleischmann] *Defining the Heat Release Rate per Unit Area for Use in Fire Safety Engineering Analysis*, Fleischmann, C., Fire Science and Technology 2015 (pp. 419-429).

[FRNSW Statistics] *New South Wales Fire Brigades Annual Statistical Report 2006/07,* NSW Fire Brigades, State Government of NSW, Sydney South, Australia, 2007.

[Hall Jr.] *US Experience with Sprinklers and other Automatic Fire Extinguishing Equipment,* Hall Jr., John, National Fire Protection Association, 2010.

[Hansen] *Full-Scale Fire Experiments with Mining Vehicles in an Underground Mine*, Hansen, R., Ingason, H., Studies in Sustainable Technology, Malardalen University, Sweden, 2013.

[IFEG] *International Fire Engineering Guidelines*, Australian Building Code Board, 2005.

[NFPA 92] *NFPA 92: Standards for Smoke Control Systems*, National Fire Protection Association, 1995.

[NIST 1019-5] *Fire Dynamics Simulator User's Guide*, McGratten, K., Klein, B., Hostikka, S., Floyd, J., National Institute of Standards and Technology, US, Version 5.

[PD7974.1] *Application of Fire Safety Engineering Principles to the design of buildings – Initiation and Development of fire within the enclosure of origin*, British Standards Institution, 2003.

[PD7974.6] *The application of fire safety engineering principles to fire safety design of buildings. Human factors. Life safety strategies. Occupant evacuation, behaviour and condition*, British Standards Institution, 2004.

[Purser] *Combustion Toxicity.* In SFPE Handbook of Fire Protection Engineering 5th Edition (pp. 2207-2307), Purser, D. A., 2016.

[ResourceCo] Resource Co. Company Overview <http://www.resourceco.com.au/file/14>

[SFPE] *Handbook of Fire Protection Engineering,* Society of Fire Protection Engineers (SFPE) 4th Edition, 2008.

[Schifiliti] *Design of Detection Systems.* In SFPE Handbook of Fire Protection Engineering 5th Edition (pp. 1314-1377*)*. Schifiliti, R. P., Custer, R. L., & Meacham, B. J., 2016.

[Steinfeld] *Automated Doors: State of the Art Report*, US Access Board, Washington DC, 1993.

[Tsiamis] *Determining Accurate Heating values of non-recycled plastics (NRP),* Tsiamis, D., Castaldi, M., Earth Engineering Centre, City College of New York, 2016.

[Ucuncu]	*Energy Recovery from Mixed Paper Waste*, Ucuncu, Aysen., Department of Civil and Environmental Engineering, Duke University, 1993.

1.7.3 Australifpuran Standards

[AS1851]	AS 1851 – 2012. *Routine Service of Fire Protection Systems and Equipment.*
[AS 1670.1]	AS 1670.1 – 2015. *Fire detection, warning, control and intercom systems, system design, installation and commissioning – Fire*.
[AS2118.1]	AS 2118.1 – 1999. *Automatic fire sprinkler systems - General requirements*.
[AS2293.1]	AS 2293.1 – 2005 *Emergency escape lighting and exit signs for buildings - System design, installation and operation*.
[AS2419.1]	AS 2419.1 – 2005. *Fire hydrant installations - System design, installation and commissioning*
[AS2441]	AS 2441 – 2005. *Installation of hose reels*.
[AS2444]	AS 2444 – 2001. *Portable fire extinguishers and fire blankets – Selection and location*
[AS3745]	AS 3745 – 2010. *Planning for emergencies in facilities*.

2 Principal Building and Occupant Characteristics

2.1 Principal Building Characteristics

2.1.1 Location

The development is located at 35-37 Frank Street, Wetherill Park, New South Wales, 2164. The overall site is bounded by Frank Street to the south, with existing industrial tenancies to the east, west and north.

No special hazards have been identified at the adjoining boundaries and given the protected location of the building, relative adjoining fire source features; the risk of fire spread between buildings is relatively low. It is noted however that a transmission easement transects the lot, however no buildings shall be built on the easement itself. Fire Services can access the overall site via Frank Street as shown in Figure 1.

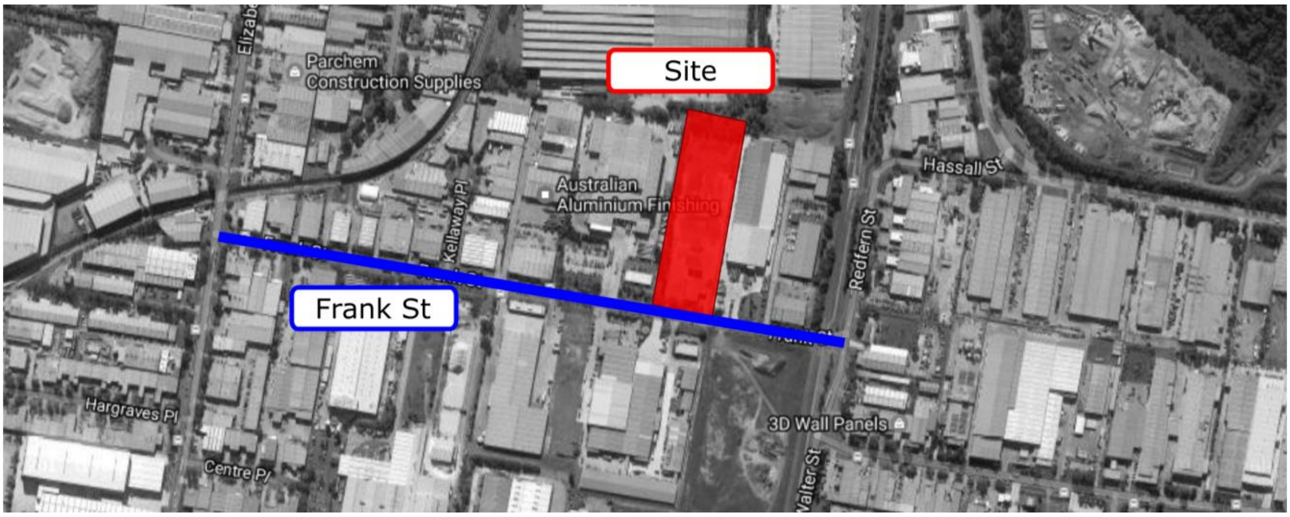


Figure 1: Street map showing brigade access (©2016 Sinclair Knight Merz, Map data ©2016 Google)

The two closest stations are listed in Table 5.

Table 5: Responding fire services

Station Location	Road Distance (Google Maps – ©2016 Google)
SMITHFIELD FIRE STATION 875 The Horsley Drive, Smithfield, NSW 2164	2.3 km
YENNORA FIRE STATION 198 Fairfield Road, Yennora NSW 2161	6.8 km

2.1.2 Size and shape

The site will contain two separate buildings, divided by a carparking area which also serves as the transmission line easement. The primary building on site is a large manufacturing building, similar to a warehouse design. The secondary building consists of a workshop and office area.

The manufacturing building is designated as a large isolated building, and has the corresponding perimeter vehicular access road encircling the building. The interior of the manufacturing building is an open plan design to allow manoeuvrability of vehicles, necessary for the loading and unloading of stock with regards to the machinery planned for the interior.

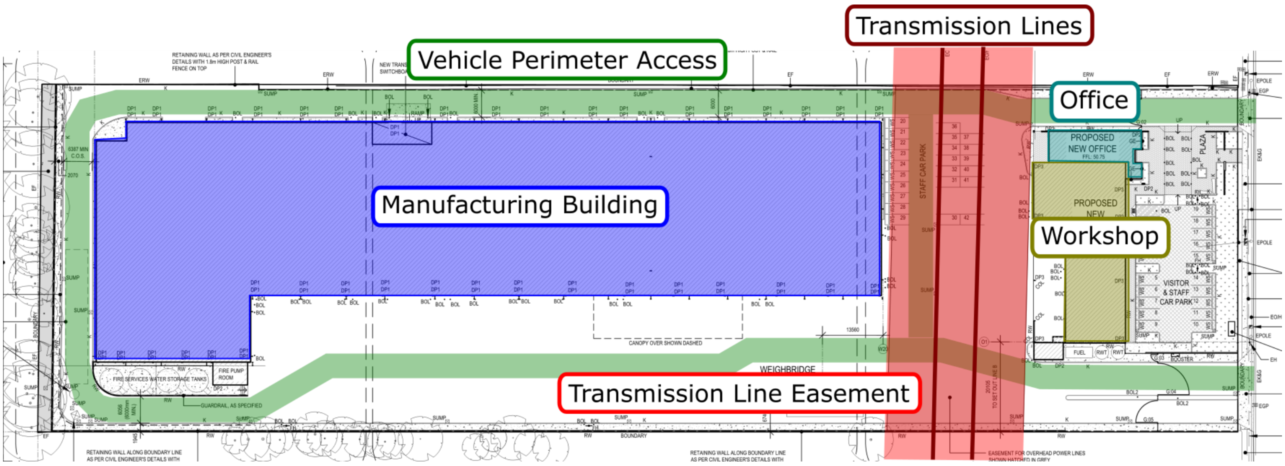


Figure 2: Overall Site Layout

2.1.3 Occupancy

The manufacturing building is to be designated for the production of processed engineered fuel, referred to as PEF. The manufacturing process takes commercial, industrial, and construction waste streams, separates them into potentially usable components, and then breaks down/shreds the combustible materials into PEF for use in various processes offsite. An example of Resource Co.'s manufacturing process is depicted in Figure 3. A more detailed discussion on the waste and PEF in the building is provided in Section 4.

The workshop and office building support both the manufacturing building and the overall business unit.

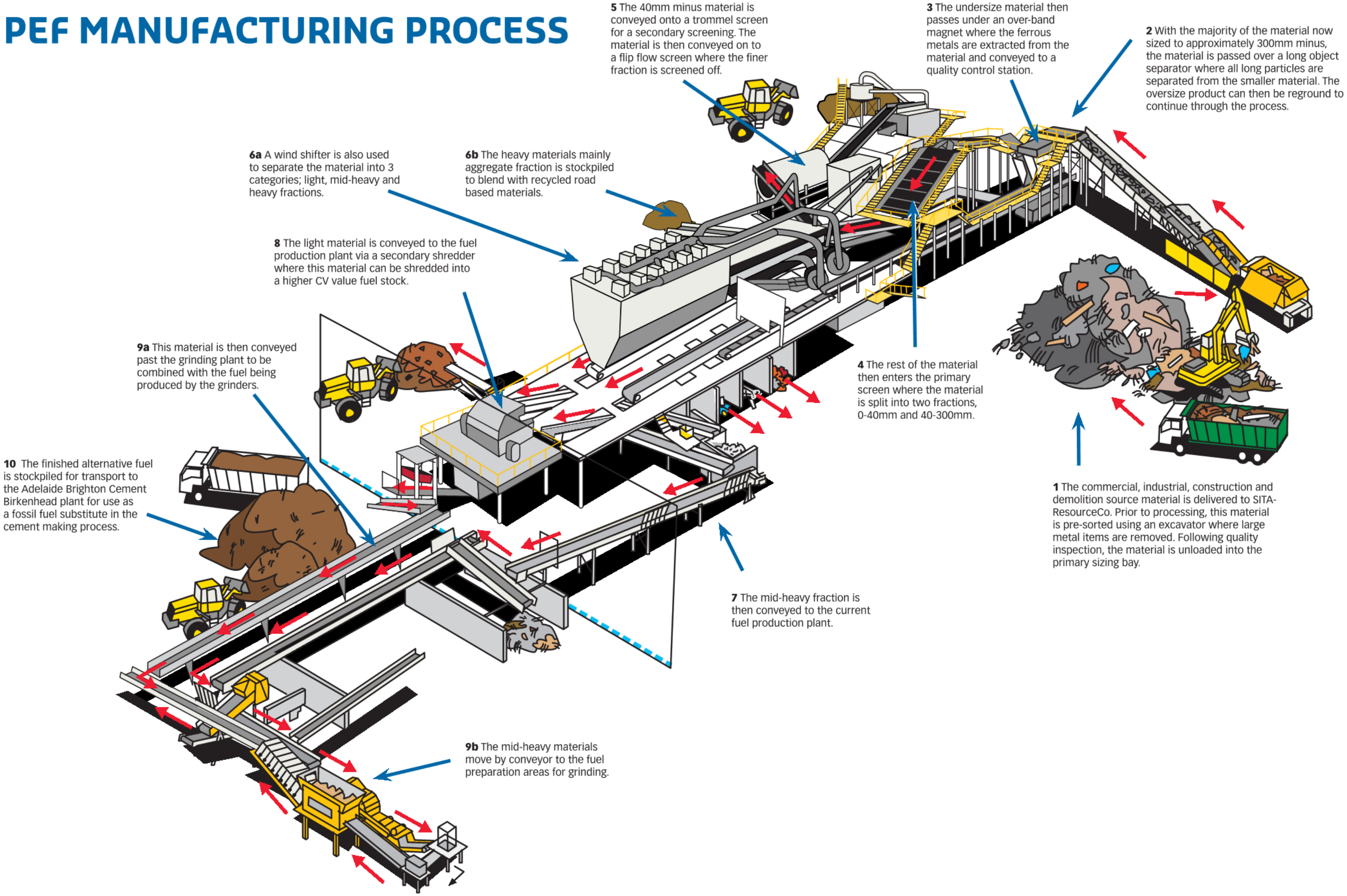


Figure 3: Example of PEF Manufacturing [ResourceCo]

2.2 Occupant Characteristics

Building occupants are considered to be primarily staff, or visitors such as truck drivers. All occupants are assumed to be representative of the general population with no specific or unusual distributions in respect to gender, age and physical or mental attributes.

Staff are expected to be familiar with the layout of the building and the location of exits. Any hearing, visual or mobility impaired staff are assumed to be able to self-evacuate or be assisted by other staff members. Staff members shall be trained in the use of first attack firefighting equipment i.e. fire hose reels and portable fire extinguishers, though this is not relied upon for the Performance Solutions.

The manufacturing building is planned to operate 2 shifts on weekdays:

Day shift: 5.00am – 2.30pm

Night shift: 2.30pm – 10pm

On Saturdays and Sundays there will be a day shift from 8am – 4pm.

The proponent has advised that the expected total population of the manufacturing building will be 20 people during any single shift.

Visitors are unlikely to be familiar with the manufacturing building layout. However, whilst the simple layout and clear signage should ensure occupants can make their way to exits readily, visitors are likely to be escorted while in the building by members of staff.

3 Building Fire Safety

3.1 BCA Reference Characteristics

The PCA has identified the building information listed in Table 6.

Table 6: Basic Building Information

BCA Clause		Description or Requirement
A1.1	Effective Height	Both buildings <12 m
A3.2	Occupancy Classification	Office/Workshop building – Class 5 & 8 Manufacturing building – Class 8
C1.1	Minimum Type of Construction	Office/Workshop building – Type C Manufacturing building – Type C (Large Isolated Building)
C1.2	Rise in Storeys	Office/Workshop building – 2 Manufacturing building – 1
C2.2	Fire Compartment Floor Area and Volume	Both buildings: Area < 18,000 m^2 Volume < 108,000 m^3

3.2 Summary of the DtS Non-Compliances

The Table 7 lists variations to the BCA DtS Provisions that have been identified by the PCA and addressed in this report:

Table 7: Summary of DtS Non-Compliances

Sol.	Description of DtS non-compliance	DtS Clause	Performance Requirement	IFEG Sub-systems
1	The vehicular perimeter access requires passing through gated entry points, as well as travelling over a transmission line easement for one part of the access.	C2.4	CP9	F
2	Travel distances within the manufacturing building are expected to be in excess of DtS compliant values, to the extent of: ▪ Up to 30 m to a point of choice in lieu of 20 m. ▪ Up to 60 m to an exit in lieu of 40 m. ▪ Up to 80 m between exits in lieu of 60 m. As well, exit signage in the manufacturing building may be installed up to 4 m above the floor level, in excess of the recommended 2.7 m height from AS2293.1.	D1.4, D1.5, E4.8	DP4, EP2.2, EP4.2	B, D, E, F
3	Travel distances within on the first floor of the office is extended up to 25 m to a single exit, in lieu of 20 m.	D1.4	DP4, EP2.2	E, F
4	The sliding doors to the office areas shall not meet the requirement of automatically failing open upon alarm or power failure.	D2.19	DP2	E, F

3.3 Fire Safety Strategy

The building's main fire safety features are described in this section.

3.3.1 Means of escape

The egress from both the manufacturing building and office/workshop building are depicted in the following figures. Egress provisions are provided around the perimeter of the manufacturing building, with the office and workshop both having two exit doors.

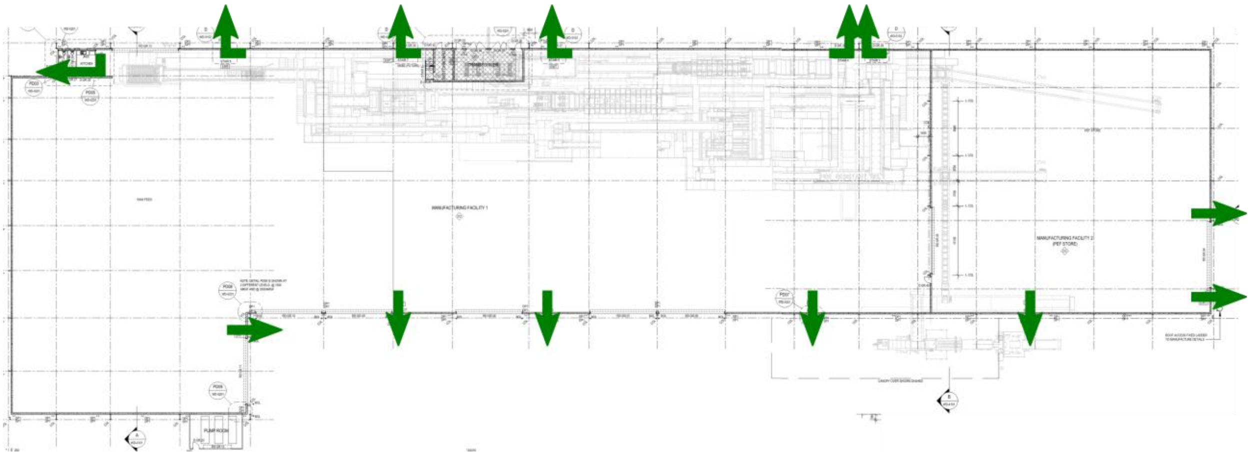


Figure 4: Egress from the Manufacturing Building

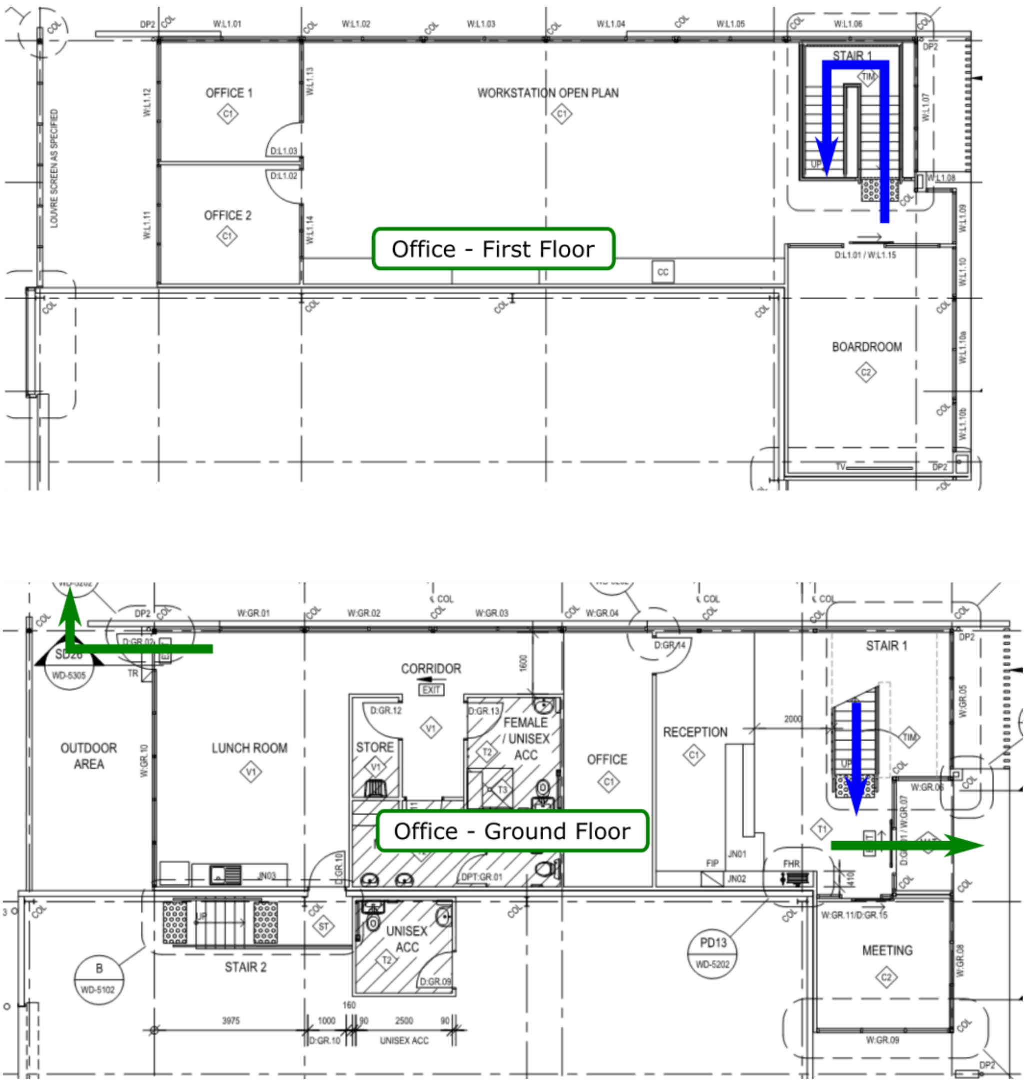


Figure 5: Egress from the Office

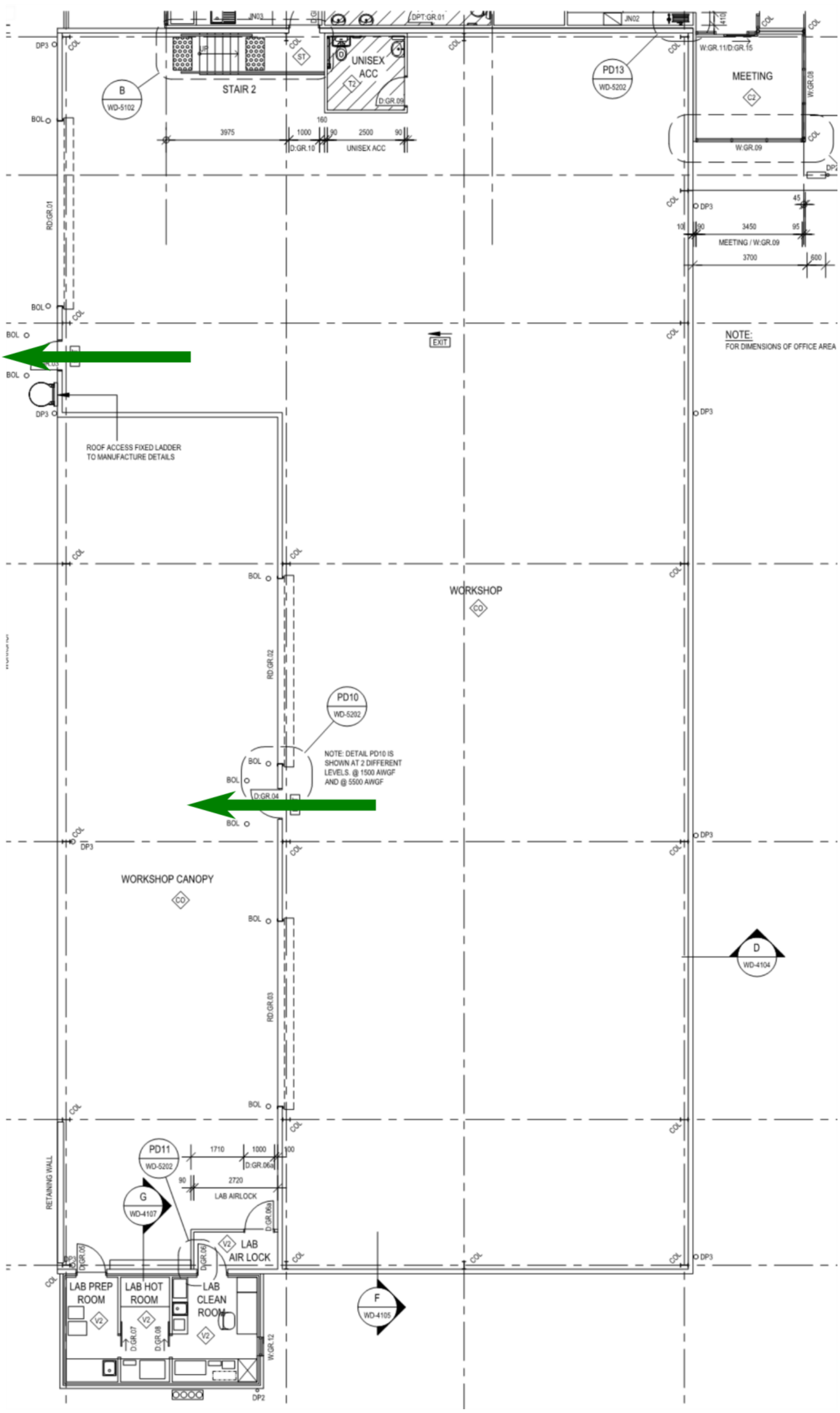


Figure 6: Egress from the Workshop

3.3.2 Fire Resistance

The manufacturing building is required to be a Type C Construction, consistent with a Large Isolated Building designation, and Type C for the workshop/office building. Building elements required to have a fire resistance level (FRL) per Specification C1.1 of the BCA shall be provided.

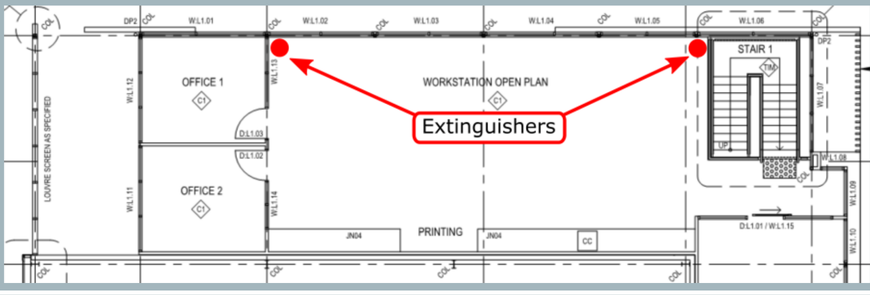
The buildings are expected to be a mixture of lightweight construction (such as steel wall cladding) and precast concrete panels.

3.3.3 Required fire safety features

The design includes the fire safety features listed in Table 8 below.

Table 8: Required Fire Safety Features

Fire Safety Measure	Description
General	If not specifically mentioned the following fire safety measures are to be provided in accordance with the Deemed-to-Satisfy provisions. This includes the provision of: ▪ Automatic Fire sprinkler system (AS 2118.1-1999) – Manufacturing building only ▪ Automatic signalling equipment ▪ Building Occupant Warning System (1670.1-2015) – Manufacturing building only ▪ Emergency lighting and exit signs (AS 2293.1-2005) ▪ Fire hose reels (AS 2441-2005) ▪ Fire Hydrant System (AS 2419.1-2005) ▪ Portable fire extinguisher (AS 2444-2001) ▪ Statutory signage
Construction Requirements	Fire Resistance, Stability and Hazard Properties In accordance with Part C of the BCA.
Perimeter Vehicular Access	Perimeter vehicular access to the site is to be provided in accordance with BCA Clause C2.4, with the exception that gates at the entry to the site may be closed and passage of roadway will be over the transmission line easement. The following additional requirements are made: ▪ Gates and security checkpoints in the emergency vehicle travel path are to be secured with a loose chain and 003 type padlock or be provided with locking devices that can be unlocked by key (i.e. provided to the two nearest local fire stations) and be manually released or operated onsite (i.e. manual override). ▪ Hydrant valves are to be located clear of the transmission line easement. ▪ Any hydrant valves located within 10 m of the transmission line easement will have signage posted to be clearly visible to fire brigade personnel before operation of the hydrants. This sign will be similar to the sign below which is in accordance with WorkCover Code of Practice for Overhead Power Lines. This sign, or one similar, shall also be posted at each entry to the site.  ▪ The location of the transmission line easement is to be included on each block plan throughout the site (i.e. at the FIP, hydrant booster, and pump room).

Fire Safety Measure	Description
Fire hydrant system	A fire hydrant system shall be provided in accordance with BCA Clause E1.3 and AS 2419.1, with the additional FRNSW Special hazard requirement that the system shall be capable of supplying a minimum 40 L/s for at least 4 hours.
Fire hose reels	Fire hose reels shall be provided in accordance with BCA Clause E1.4 and AS 2441.
Portable fire extinguishers	Portable fire extinguishers will be provided in accordance with BCA Clause E1.6 and AS2444. As per Section 5.3 of this report – two additional, multi-purpose Type ABE dry powder fire extinguishers (minimum 2.5 kg size) shall be provided to the first floor office area, in approximately the locations depicted below. 
Fire sprinkler systems	A fire sprinkler system in accordance with AS2118.1 and BCA Clause E1.5 shall be provided throughout the manufacturing building. The response time index of the sprinklers shall not be greater than 50 $m^{1/2}s^{1/2}$.
Building Occupant Warning System (BOWS)	A building occupant warning system in accordance with AS1670.1 shall be provided throughout the manufacturing building. Activation of the fire sprinkler system shall activate the building occupant warning system. Emergency manual call points in accordance with AS1670.1 shall be provided within the manufacturing building. The manual call points shall be white in colour and designed in accordance with the 'Emergency Warning' functionality of Clause 3.15 of AS1670.1 to activate the building occupant warning system only. These manual call points shall be distributed to the exits from the manufacturing building.
Emergency lighting and exit signs	Emergency lighting and exit signage shall be provided in accordance with BCA Clause E4.2 and E4.5 respectively, and AS2293.1, with the exception that exit sign heights may be up to 4 m above the ground level in the manufacturing building. The extended height signs are to be 'Jumbo' signs.
Management in use	An emergency management plan in accordance with AS 3745 shall be provided.
Maintenance	A maintenance program shall be developed with all essential safety maintained in accordance with AS1851 and AS2293.2.
FRNSW Special Hazard Requirements	In addressing the Special Hazard provision of E1.10 and E2.3 as part of the Development Consent, the following fire safety measures are required by FRNSW (See Section 4.4 and Appendix F): ▪ The stockpiles within the RAW and PEF areas shall be separated as follows: ▪ The RAW area shall be divided into at least three (3) stockpile bays, of a maximum size of 1,000 m^3. ▪ The PEF area shall be divided into at least two (2) stockpile bays, of a maximum size of 825 m^3.

Fire Safety Measure	Description
	▪ Each stockpile shall be separated from one another by 120 minute fire rated bays of masonry construction. The separating construction shall be at least 2 m high. ▪ The site shall maintain at least two (2) front end loaders on-site with bucket capacities of 4.9 m^3 each. ▪ The site shall be capable of retaining contaminated fire water flowing for up to 90 minutes, equating to approximately 470,000 L, within the footprint of the building. ▪ A ridge vent, running the length of the building at the highest point, shall be provided to meet the following requirements: ▪ Minimum throat open diameter of 1,200 mm ▪ Protected from wind via shielding for the length of the ridge vent, such that any inlet/discharge is not exposed to the horizontal movement of air or wind external to the building. ▪ The ridge vent design shall meet or exceed the design exhaust capacity noted in Section D.6, Table 27. ▪ Make-up air is to be provided by the dado-wall setback from the steel-clad wall by at least 500 mm, around the perimeter of the building. ▪ The roller shutter for the PEF storage area shall open upon sprinkler activation to provide additional make-up air and venting capabilities to the PEF area. Cabling to the roller shutters shall be in accordance with AS 1668.1.

4 Special Hazard Considerations

4.1 Designation of Special Hazard

The Development Consent contains the following condition:

A15. Prior to the commencement of construction, the final design of the development must be finalised in consultation with and to the satisfaction of Fire and Rescue NSW and include suitable additional provisions for special hazards by specifically addressing Clauses E1.10 and E2.3 of Volume One of the *National Construction Code (NCC) Series*.

This section of the Fire Engineering Report has been prepared in order to discuss and address the special hazard designation noted, as well as identifying how Clauses E1.10 and E2.3 of Volume One of the BCA have been considered.

Clause E1.10 details the following for the Provision of Special hazards, as it relates to Fire Fighting Equipment for the building:

E1.10 Provision for special hazards

Suitable additional provision must be made if special problems of fighting fire could arise because of—

(a) the nature or quantity of materials stored, displayed or used in a building or on the allotment; or

(b) the location of the building in relation to a water supply for fire-fighting purposes.

It is noted that Clause E1.10(b) would not apply in this case, as the water supply is consistent with normal operational requirements for fire-fighting purposes, as there are onsite sprinkler storage tanks and a town main connection.

Clause E1.10(a), which examines the nature or quantities of materials stored or used, shall be further considered with regard to processed engineered fuel (PEF) and the material it is being derived from. These elements have been highlighted as being outside the norm by FRNSW.

Clause E2.3 relates to smoke hazard management for the building:

E2.3 Provision for special hazards

Additional smoke hazard management measures may be necessary due to the—

(a) special characteristics of the building; or

(b) special function or use of the building; or

(c) special type or quantity of materials stored, displayed or used in a building; or

(d) special mix of classifications within a building or *fire compartment*,

which are not addressed in **Tables E2.2a** and **E2.2b**.

E2.3(a) is not considered to be applicable as there are no special characteristics distinct to the building itself, being similar in design and construction with other warehouse and industrial buildings with concrete tilt-up panel and steel clad wall designs, built on top of a concrete slab.

The function or use of the building, relevant to Clause E2.3(b), is considered consistent with that of a manufacturing or production environment as defined by the BCA. From the BCA, the definition of a Class 8 building is:

*A laboratory, or a **building** in which a handicraft or **process for the production**, assembling, **altering**, repairing, packing, finishing, or cleaning of **goods** or produce is carried on for **trade, sale, or gain**.*

The manufacturing building in question falls within this criteria, as its function as a building is to take in waste material, and alter/finish/clean the goods (through separation/mechanical processes), for trade, sale or gain. This process is consistent with the function or use of the building.

For E2.3(d), the manufacturing building is a single fire compartment with a single classification (Class 8), thereby would not constitute a special mix of classifications.

Similar to E1.10, the remaining special hazard consideration (E2.3(c)) is in regards to a 's*pecial type or quantity of material stored in a building'*. The PEF manufactured at this site, as well as the waste material it is developed from, fit the criteria to be considered further. It is therefore this element (the PEF/waste materials) that will be discussed in the following sections.

4.2 Processed Engineered Fuel (PEF)

PEF is a manufactured fuel, derived originally from disparate waste streams such as commercial and industrial wastes. Within the manufacturing building, the original waste source, and the final PEF materials form two storage areas, and hence the primary fuel loads to be examined.

The incoming waste stream is expected to consist of partially pre-sorted industrial, construction, and commercial wastes. Non-combustible materials will make up a portion of this initial waste stream, which in effect would act to reduce the potential fuel load and flammability of the waste stream. However, as a conservative measure and because the non-combustible element is not defined or controlled, nor significant to the hazard, the non-combustible elements are ignored for this assessment.

The majority of the incoming waste stream is expected to consist of various combustible elements, ranging from wood, paper, plastics and other cellulosic materials. These materials, having been derived from industrial, commercial and construction wastes, would not be considered to be any more significantly combustible than the original components they came from. That is, the incoming waste stream is not expected to pose an increased fire hazard over that of a standard warehouse, distribution or manufacturing environment, as the waste stream would come from materials that originated from those facilities.

This has been demonstrated in past studies on mixtures of combustible materials, which have shown that the expected calorific value (and hence, fuel load) is averaged, rather than an increased, by having a mixture of wastes [Ucuncu]. By mechanically mixing materials together (rather than chemically altering them together via reaction), it can be expected that the waste stream would represent a fire profile somewhere in between its disparate parts. Which in this case, those disparate parts being wood, paper, plastics and other cellulosic material, are commonly found in warehouse type environments and do not constitute a special hazard typically.

This consideration follows on to the PEF. The process that creates the PEF is a mechanical one [Fisher], and depicted in Figure 3. The waste stream is sorted, low calorific elements removed where possible, and then the waste stream is mechanically shredded (for larger elements) into smaller elements, and the final products dried to remove excess moisture which may have been absorbed through waste storage or processing. Throughout the process however, the chemical composition of the elements have not changed nor has the *maximum* calorific value of the PEF exceeded that of its highest component value (typically, plastics). The PEF process has removed the lower calorific valued elements to increase the average calorific value of the mixture. This is the core of the PEF process – increased value through separation.

Because of this key identification, the final PEF product would not exceed the calorific value or overall fuel load of a pure fuel load of combustible content such as wood or plastics. This is demonstrated in the following image, which compares PEF against multiple different fuels.

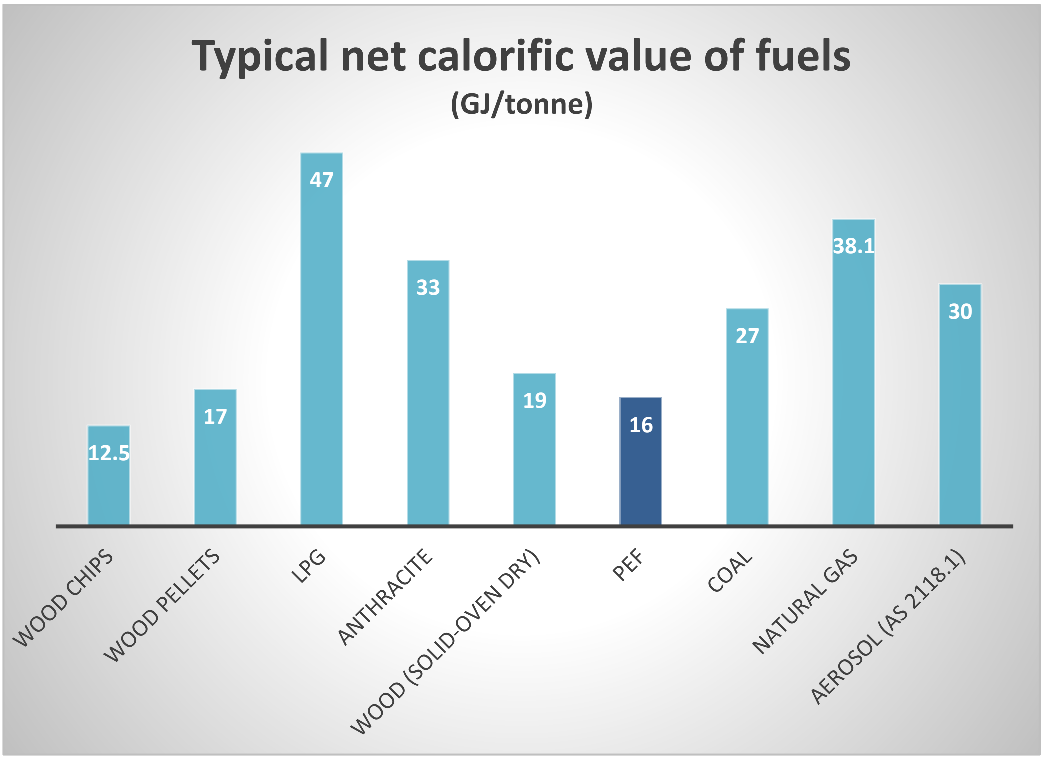


Figure 7: Calorific Value of Common Fuels (Biomass Energy Centre 2016)

The net calorific value of PEF sits very much in the low range of fuels, being less than wood pellets or wood, which may be found in typical manufacturing and warehouse sites in large quantities. It is further noted that plastics in particular have high calorific values, in the 30-40+ GJ/tonne range [Tsiamis] and a warehouse with significant plastic content would exhibit an equivalent, if not higher fuel loads and fire hazards. The presence of the PEF and its originating waste stream are therefore not expected to pose an increased fire hazard, above that of a typical warehouse or manufacturing building.

4.3 Implications within this Fire Engineering Report

While the analysis in Section 4.2 is considered to demonstrate that the materials within the building are not considered to pose an increased or special hazard with regards to fire and smoke, this Fire Engineering Report has nonetheless integrated additional conservatism into the Performance Solution analysis in order to demonstrate the suitability of the fire safety systems. Performance Solution #2 utilises Computational Fluid Dynamic modelling on the manufacturing building to demonstrate not only occupant egress acceptability but also fire brigade intervention acceptability. The provision of CFD considers the effects of both fire and smoke on occupants.

In order to ensure that any hazard consideration is included within the Performance Solution and associated CFD modelling, the most conservative element of any input was used, with further factors of safety added on top of this. This is directly applicable to the fire size modelled within the CFD models.

Fire sizes for CFD analysis can be developed in multiple ways. Within the BCA, Specification E2.2b, Figure 2 describes various prescriptive fire loads for different classifications when designing exhaust rates. For a Class 8 building, a 5 MW fire load is considered an appropriate fire size in a sprinkler protected building (base case), whereas a 15 MW fire load is appropriate for an unsprinklered building (sensitivity case). Calculations from 1st principles using sprinkler activation also can be used to determine potential fire sizes.

One calculation method for fire size and detector activation is Alpert's correlation. When Alpert's correlation is utilised, multiple elements of consideration must be taken into account in order to determine when sprinklers would activate and control a fire size. Most relevant here are the radial distance from a fire source to a sprinkler head, the height from the fire base to a sprinkler, and the speed of fire growth.

With respect to the speed of fire growth, the most commonly used models are the t^2 growth curves, as described in the [NFPA 92]. [PD 7974.1] provides further guidance on the characteristic fire growth rate for different types of occupancies. For an industrial environment it recommends an ultra-fast-t^2 growth rate, which is utilised here for the fire size calculations.

With regards to radial distance from a fire source to a sprinkler head, the calculation uses the furthest possible point on a sprinkler array, which in this case would be 2.12 m based on a 3 m x 3 m sprinkler grid. This is the most conservative possible placement. In reality, fires may occur anywhere between 0 m (directly underneath) to 2.12 m radially distant from a sprinkler head (centre of the sprinkler array).

This conservatism is taken further for the sensitivity analysis of sprinkler activation, which assumes the first row of sprinklers fail to activate, allowing a fire to grow until controlled by the second row of sprinklers. In effect, this allows for a much larger fire size as a sensitivity scenario, and again assumes that the fire is centrally placed at distances furthest from any single sprinkler head. Therefore, the sensitivity scenario considers that the 4 closest sprinkler heads fail to activate or control the fire, and instead relies on the 5th closest sprinkler head, and beyond, for activation.

With regards to height, as the manufacturing building is expected to use pile storage rather than rack storage for the waste material and PEF, the height differential between a fire source and a sprinkler head would typically be considered from the *top* of the proposed pile, to the sprinkler head. However, the analysis, as a further point of conservatism, instead will assume the height differential to be the maximum possible between a low level of fuel above ground level and the sprinklers at roof level, at the peak of the roof. The degree of separation between the sprinkler and fire is therefore taken as 13 m.

Given the above conservative factors and assumptions, Alpert's correlation would provide a 9 MW fire load for the base case, and 19 MW fire load for the sensitivity case.

In the Performance Solution, fire loads are set at 10 MW for the base case, and 20 MW for the sensitivity case. This represents, for a sprinkler protected building such as this, a safety factor of 2x and 4x over the representative fire load of the BCA, and further, a safety factor of 1.3x for the sensitivity case over an *unsprinklered* building. They also represent a safety factor greater than 1 compared to fire loads estimated from first principles using multiple conservative assumptions. These safety factors indicate a high degree of conservatism and therefore there is confidence in the selected design fires utilised in the Performance Solution modelling and analysis.

Finally, the application of 10 MW and 20 MW is considered appropriate fire sizes based on other fire hazards within the manufacturing building. While the special hazard is considered to be from the waste material and PEF, the movement of these elements is done using heavy vehicle loaders. These loaders represent a mobile fire load, and while largely made up of steel frames and bodies, their large tires and other combustible elements still represent a significant fire potential.

[Hansen] performed full scale fire experiments on loading vehicles similar to the ones anticipated for use at this site. Their full scale fire experiment determined that the maximum heat release rate of a heavy loader could be up to approximately 16 MW, ignoring any potential suppression systems. In the manufacturing building's case, the sprinklers provided throughout the building would likely activate and supress the fire prior to this value being reached, however, it gives further substantiation that the values chosen for the analysis are suitably conservative.

As discussed, the analysis of Performance Solution #2 includes numerous conservative elements to ensure that the design of the building takes into account the special hazard nominated by the conditions of consent. In demonstrating that the Performance Requirements have been met, the analysis of Performance Solution #2, by integrating all of these conservative elements, will also have demonstrated that the fire safety systems provided to the building, are appropriate for the level of hazard found on the site for occupants.

4.4 Fire and Rescue New South Wales Requirements

As a key stakeholder in the fire safety of the building, Fire and Rescue New South Wales gave input into the design based on the Special Hazard designation. This input led to the following Fire Safety Measures being incorporated into Table 8:

- The stockpiles within the RAW and PEF areas shall be separated as follows:
    - The RAW area shall be divided into at least three (3) stockpile bays, of a maximum size of 1,000 m^3.
    - The PEF area shall be divided into at least two (2) stockpile bays, of a maximum size of 825 m^3.
    - Each stockpile shall be separated from one another by 120 minute fire rated bays of masonry construction. The separating construction shall be at least 2 m high.
    - The site shall maintain at least two (2) front end loaders on-site with bucket capacities of 4.9 m^3 each.
- The site shall be capable of retaining contaminated fire water flowing for up to 90 minutes, equating to approximately 470,000 L, within the footprint of the building.
- A ridge vent, running the length of the building at the highest point, shall be provided to meet the following requirements:
    - Minimum throat open diameter of 1,200 mm
    - Protected from wind via shielding for the length of the ridge vent, such that any inlet/discharge is not exposed to the horizontal movement of air or wind external to the building.
    - The ridge vent design shall meet or exceed the design exhaust capacity noted in Section D.6, Table 27.
- Make-up air is to be provided by the dado-wall setback from the steel-clad wall by at least 500 mm, around the perimeter of the building.
- The roller shutter for the PEF storage area shall open upon sprinkler activation to provide additional make-up air and venting capabilities to the PEF area. Cabling to the roller shutters shall be in accordance with AS 1668.1

The stockpile sizes, hydrant system and contaminated fire water design was developed through correspondence with FRNSW, the final confirmation being provided in Appendix F.

The smoke hazard management ridge vent and make-up air design was developed through computational fluid dynamic modelling, with FRNSW correspondence and feedback. The modelling details are provided in Appendix D, with the results provided in Appendix E, and FRNSW correspondence and feedback in Appendix F.

5 Performance Solutions

5.1 Solution 1: Perimeter Vehicular Access

5.1.1 Introduction

As a large isolated building, the manufacturing building is to be provided with vehicular perimeter access per Clause C2.3 and C2.4. Clause C2.4 requires that the access be unobstructed and allow the continuous movement of emergency vehicles, however as depicted in Figure 8, gated entry points exist from the access road, potentially restricting vehicular movement.

Further to the above, a transmission line easement crosses the vehicle access pathway, again depicted in Figure 8. While not prescriptively a DtS non-compliance, the crossing of high level transmission lines will nonetheless be considered as part of the Performance Solution.

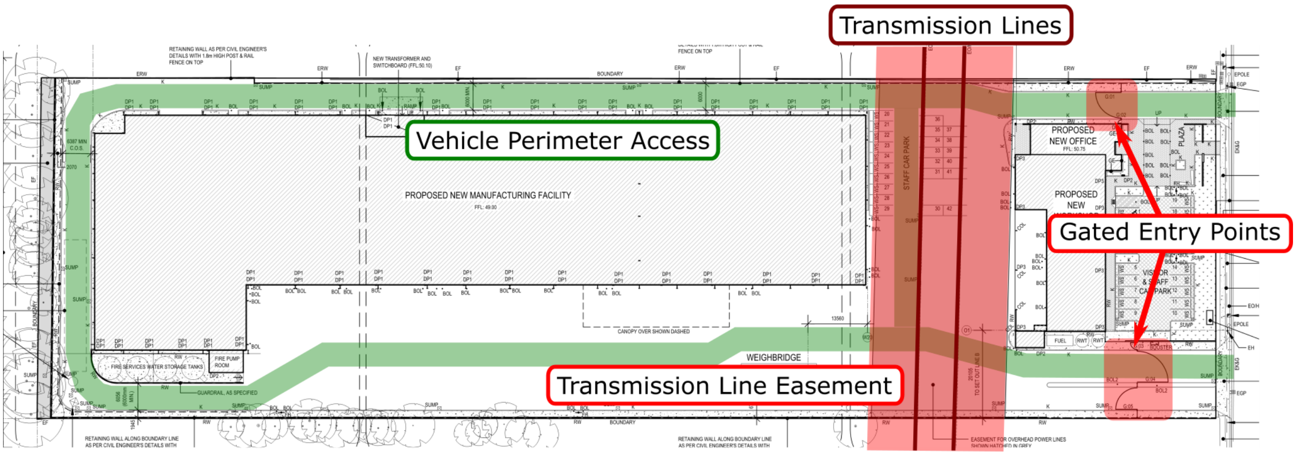


Figure 8: Perimeter Vehicular Access and areas of issue

Table 9 provides a summary of this DtS non-compliance, the relevant BCA DtS Provisions, which are affected, and the relevant BCA Performance Requirements and IFEG sub-systems.

Table 9: Summary of DtS non-compliance

No	Description of DtS non-compliance	DtS Clause	Performance Requirement	IFEG Sub-systems
1	The vehicular perimeter access requires passing through gated entry points, as well as travelling over a transmission line easement for one part of the access.	C2.4	CP9	F

5.1.2 Intent of the BCA

5.1.2.1 BCA Clause C2.4

BCA Clause C2.4 describes the requirements for open spaces and vehicular access requirements, related to Large Isolated Buildings. Of relevance here, Clause C2.4 requires that the vehicular access must provide continuous and unobstructed access for emergency vehicles to enable travel in a forward direction around the entire building. The intent is to ensure that emergency vehicles are not delayed in accessing areas around a large building, from which intervention activities may be undertaken.

5.1.2.2 BCA Performance Requirement CP9

BCA Performance Requirement CP9 relates to fire brigade access to a building to facilitate brigade intervention activities. The Performance Requirement requires consideration as to the function of the building, the fire load, intensity and hazard, what fire safety systems are installed within the building as well as fire compartment sizes. Of particular relevance here is the consideration for vehicular movement around the site, predicated by Clause C2.4. The unrestricted nature of the access is critical to ensure all hours access to attending fire brigade appliances, and therefore access at all times must be taken into consideration.

5.1.3 Approach and assessment method

The approach is qualitative and absolute using the assessment methods as shown in Table 10.

Table 10: Approach and Assessment Method used

BCA Clause A0.3	BCA Clause A0.5
A Performance Solution must: **(a) comply with the Performance Requirements; or** (b) be at least equivalent to the Deemed-to-Satisfy Provisions, and be assessed according to one or more of the Assessment Methods.	**The following Assessment Methods, or any combination of them, can be used to determine a Performance Solution or a Deemed-to-Satisfy Solution complies with the Performance Requirements:** (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 of the BCA. **(b) Verification methods such as—** (i) the Verification Methods in the BCA; 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

5.1.4 Fire safety design requirements

The fire safety measures listed in Table 8 form the holistic fire safety design for the building's Performance Solutions. The additional fire safety measures specific to this Performance Solution are as follows:

- Gates and security checkpoints in the emergency vehicle travel path are to be secured with a loose chain and 003 type padlock or be provided with locking devices that can be unlocked by key (i.e. provided to the two nearest local fire stations) and be manually released or operated onsite (i.e. manual override).
- Hydrant valves are to be located clear of the transmission line easement.
- Any hydrant valves located within 10 m of the transmission line easement will have signage posted to be clearly visible to fire brigade personnel before operation of the hydrants. This sign will be similar to the sign below which is in accordance with WorkCover Code of Practice for Overhead Power Lines. This sign, or one similar, shall also be posted at each entry to the site.

- The location of the transmission line easement is to be included on each block plan throughout the site (i.e. at the FIP, hydrant booster, and pump room).

5.1.5 Acceptance criteria

Fire brigade intervention must not be hindered by the inclusion of gate entries to the site, and there must be suitable warning as to the raise awareness of FRNSW as to the location of transmission lines on the site.

5.1.6 Method of analysis

The analysis shall qualitatively examine the perimeter access pathway for both suitability of brigade movement and set up activities, as well as separation of risk for firefighting intervention.

5.1.7 Hazards

With regards to the security gates, the hazard stems from potentially delaying emergency vehicle access to the site. While during operational hours it can be expected that sufficient access to the site can be more ensured due to the gates being open to permit movement of normal vehicles, after hours, when the site is secure, a delay of access may occur. If brigade access is unnecessarily delayed, there exists the potential that a fire could spread, grow more intense, and become more difficult for brigade intervention activities.

For the high voltage lines, the primary hazard is from the use of water near electrically charged areas, as well as the potential for arching of electricity through smoke to occur. The transmission easement itself sets aside specified dimensions and clear areas from the transmission lines to reduce the potential of this occurring, however ensuring brigade intervention activities are not staged within the easement area is critical from an electrical safety perspective.

5.1.8 Analysis

5.1.8.1 Compliance with other Provisions of C2.4

In analysing the DtS non-compliance, it is also important to highlight how the perimeter access around the building is provided, and detailing how and where compliance has been met.

Clause C2.4 of the BCA requires the following, which has been compared to how the site provides compliance:

Table 11: Clause C2.4(b) requirements compared against the Performance Solution

Clause C2.4(b) requirements	Performance Solution Design
Must be capable of providing continuous access for emergency vehicles to enable travel in a forward direction from a public road around the entire building; and	This has been provided to the manufacturing building, as continuous movement is provided through the internal roadways, accessed from Frank Street. The only potential obstruction comes from the gates, which provide acceptable width requirements, but may be closed and secure outside of operating hours.
Must have a minimum unobstructed width of 6 m with no part of its furthest boundary more than 18 m from the building and in no part of the 6 m width be built upon or used for any purpose other than vehicular or pedestrian movement; and	The width of all roadways meet the 6 m width requirements throughout the site.
Must provide reasonable pedestrian access from the vehicular access to the building; and	Pedestrian access from the vehicular access path is readily available at multiple locations around the site.
Must have a load bearing capacity and unobstructed height to permit the operation and passage of fire brigade vehicles; and	The vehicular access path and clear heights will have the load bearing capacity in line with fire brigade requirements, noting that the electrical easement is not considered an area for intervention activities.

Clause C2.4(b) requirements	Performance Solution Design
Must be wholly within the allotment except that a public road complying with (i), (ii), (iii) and (iv) may serve as the vehicular access or part thereof.	Public road access from Frank Street is provided from one side of the site, with the remainder of the vehicular access being provided by the dedicated internal roadway.

From Table 11 it is seen that the Performance Solution provides for all of the key access criteria, with the exception that after hours, the gates *may* obstruct the initial access to the site. However, on the site itself the vehicular access provides numerous staging areas and access to the manufacturing building as well as DtS compliant widths and capacities.

5.1.8.2 Obstruction of Vehicle Path

The entry and discharge pathway for the vehicle perimeter pathway potentially requires navigation through a security gate, which may be closed and secured when the site is not operating (i.e. night time). In this case, brigade access to the site may be restricted, such that delay may occur while opening the gate points.

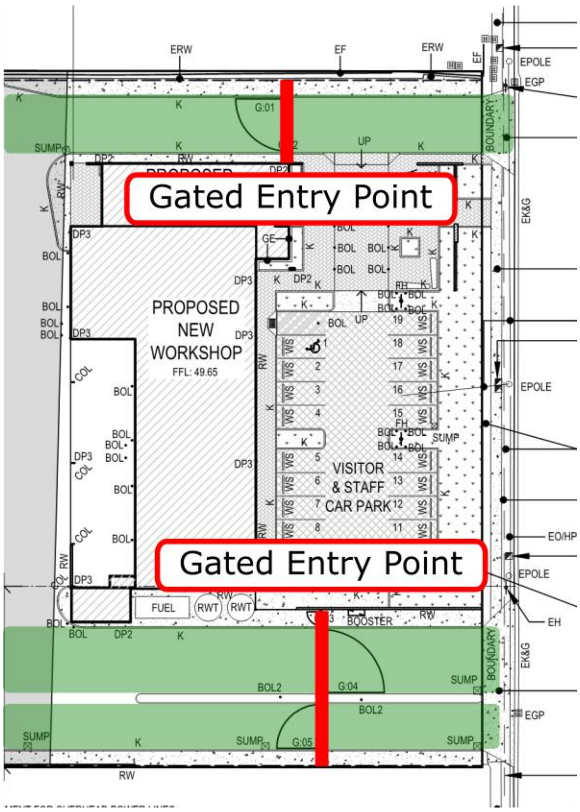


Figure 9: Gated Entry Points to the Site

The risk to delayed brigade intervention is considered to be mitigated through several aspects:

Only a single gate requires access to be able to grant full perimeter access to the manufacturing building. The interior road over the transmission easement allows the brigade to navigate a complete loop around the structure, without having to return to the public road or gate points. Therefore, the potential delay would be limited to initial access only.

FRNSW Policy Number 4 notes that security items such as gates must not *unnecessarily* impede access for brigade appliances. The gate serves a security purpose for the site only, considered to be critical from an operational and site preservation viewpoint. Therefore, the gates, as part of the daily security of the site, is considered to be a necessary addition to the site. However, to ensure that the brigade are not *unnecessarily* impeded any more than the presence of the gate creates, provisions of the Performance Solution enable the brigade to quickly overcome the security, if they wish to do so.

A loose chain with 003 keyed padlock, or a locked gate whereby the key is provided to the two nearest fire brigade stations provide FRNSW with a method of quickly overcoming a locked gate scenario. Whilst there may be a delay in unlocking the gate, any potential delay still incurred is considered to be commensurate with the lowered risk in the manufacturing building due to sprinkler protection.

The provision of sprinklers throughout the manufacturing building grants significant confidence that in a fire scenario whereby FRNSW has been alerted, sprinklers will actuate to control or suppress a fire. From [Hall Jr.], sprinklers in manufacturing buildings have operated successfully in approximately 86% of fires, containing a fire to the room of origin. When considered in conjunction with the internal circulating perimeter access and the provision of an 003 key padlock or keys being provided to the two nearest brigade stations, the perimeter vehicular access around the building, inclusive of the gates, is not expected to pose an unnecessary delay to brigade intervention and the building itself has been provided with suitable measures to compensate for the gate.

5.1.8.3 Transmission Line Easement

High voltage transmission lines transect the perimeter vehicular access, requirement brigade appliance vehicles to manoeuvre under the high voltage lines to access the building. While not considered a DtS non-compliance, this deviation from the norm is nonetheless highlighted here to ensure brigade intervention activities will not be hindered.

The design of the building and intervention activities take into account the transmission line easement in the following manner:

- Hydrants are not permitted to be placed within the easement itself. All hydrant access therefore is outside the transmission line easement.
- Any hydrant access within 10 metres of the easement boundary will have clear signage warning of the nearby power lines.
- Site access points as well as all block plans on site (FIP, booster, pump room) shall clearly depict and warn of the transmission line easement.

The purpose of these measures are to ensure any attending emergency personnel are alerted to the presence of the transmission easement, as well as placing all critical equipment outside the easement area. In doing so, any brigade staging or intervention activities would be expected to take place outside the transmission easement and therefore away from any high voltage lines, consistent with normal operating procedures.

5.1.9 Conclusion

The analysis demonstrated that the use of gates to access the site, as well as the transmission line easement crossing the site, are not expected to unduly delay or hamper fire brigade intervention efforts, as suitable measures will be provided to enable afterhours access to the site, as well as ensuring all critical intervention activities are away from the transmission line easement.

5.2 Solution 2: Manufacturing Building Travel Distances

5.2.1 Introduction

As the manufacturing building exhibits wide open areas and limited exit doors, it is expected that the travel distances to a point of choice, to an exit, and between exits will be extended beyond DtS compliant distances. This is depicted in a general sense in Figure 10, noting that the actual areas of DtS non-compliance may happen in various places, but to equivalent or lesser distances.

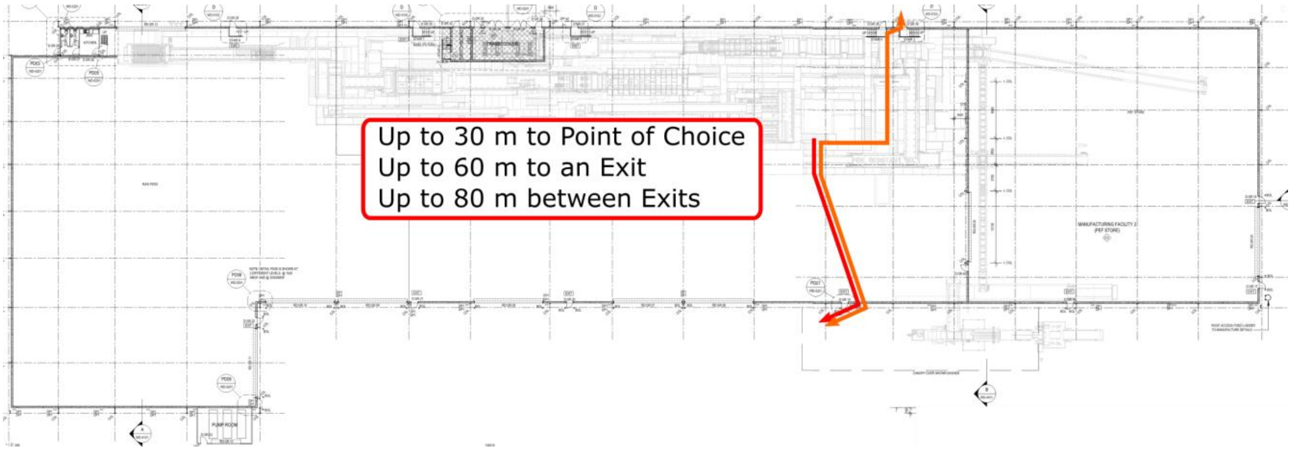


Figure 10: Extended Travel Distances in the Manufacturing Building

Table 12 provides a summary of this DtS non-compliance, the relevant BCA DtS Provisions, and the relevant BCA Performance Requirements and IFEG sub-systems.

Table 12: Summary of DtS non-compliance

No	Description of DtS non-compliance	DtS Clause	Performance Requirement	IFEG Sub-systems
2	Travel distances within the manufacturing building are expected to be in excess of DtS compliant values, to the extent of: ▪ Up to 30 m to a point of choice in lieu of 20 m. ▪ Up to 60 m to an exit in lieu of 40 m. ▪ Up to 80 m between exits in lieu of 60 m. As well, exit signage in the manufacturing building may be installed up to 4 m above the floor level, in excess of the recommended 2.7 m height from AS2293.1.	D1.4, D1.5, E4.8	DP4, EP2.2, EP4.2	B, D, E, F

5.2.2 Intent of the BCA

5.2.2.1 BCA Clause D1.4

BCA Clause D1.4 applies specified values to travel distances. The Guide to the BCA states the intent is to '*maximise the safety of occupants by enabling them to be close enough to an exit to safely evacuate'.* For Class 5-9 buildings/areas, the travel distances have been chosen based on the assumption people are awake and therefore able to react to alarm signals. As a manufacturing building, occupants can be expected to be of working age and likely to exhibit good mobility and awareness. A performance solution therefore must demonstrate that any extension of travel distances will not put occupants in situations where untenable conditions may occur before they reach safety.

5.2.2.2 BCA Clause D1.5

BCA Clause D1.5 details the distances between alternative exits. This is specified such that occupants are not required to travel excessive distances to a secondary exit in the event that their primary exit has become blocked or otherwise inaccessible. The reasoning being that excessive travel distances may impose increased risks to occupants due to the fire growth and smoke spread that could occur while occupants seek safety. A performance solution therefore must demonstrate that any extension of travel distances between exits will not put occupants in situations where untenable conditions may occur before they reach safety.

5.2.2.3 BCA Clause E4.8

BCA Clause E4.6 (NSW) states that if an exit is not readily apparent to persons occupying or visiting the building, then directional exit signs must be provided. E4.8 states that every required exit sign must comply with AS 2293.1. AS 2292.1:2005 Clause 6.8.1 recommends exit signs be mounted not less than 2 m and not more than 2.7 m above floor level. The signage height is chosen to be at a minimum level above eye height, in order to ensure the exit signage is readily visible to occupants as they egress. Heights above the norm may result in occupants not seeing signs, and the signs potentially being obscured by the effects of a fire at an earlier time.

5.2.2.4 BCA Performance Requirement DP4

BCA Performance Requirement DP4 relates to the number, dimensions and distribution of exits. In determining the compliance with this Performance Requirement, the analysis must show that occupants can evacuate safely. This is demonstrated through several aspects, including the location of exits, dimensions of exits, characteristics of occupants, and most importantly, the travel distance occupants must travel. Of particular relevance is that as travel distance increases, so does the time it takes for occupants to reach an exit or a place of safety.

5.2.2.5 BCA Performance Requirement EP2.2

BCA Performance Requirement EP2.2 relates to the evacuation routes themselves, ensuring that they must remain tenable. From the Guide to the BCA, '*Occupants must be given time to evacuate before the onset of untenable conditions*.' EP2.2 expands upon the untenable conditions to consider the temperature, visibility and toxicity within the evacuation route, and that the period of evacuation shall be relevant to a number of aspects, including occupant characteristics and travel distances. Therefore, in satisfying EP2.2, it must be demonstrated that occupants shall be provided with tenable conditions during their egress, either in comparison to a Deemed-to-Satisfy design or absolutely.

5.2.2.6 BCA Performance Requirement EP4.2

BCA Performance Requirement EP4.2 details that suitable signs are to be provided to facilitate evacuation, be clearly visible to occupants and guide occupants to exits. The Performance Requirement also includes the phrase 'to the degree necessary', which indicates that the exit signage requirements are to be assessed for each building to determine how many, where, and what signage is provided. This is further developed in the Guide to the BCA, which indicates 'that not all buildings need signs or markers to facilitate evacuation.' The Guide to the BCA then furthers this by providing an example whereby simple layouts, familiar occupants, and good normal visibility may result in a suitable design which requires *no* exit signs whatsoever. It therefore is apparent that the design of exit signage is highly dependent on the classification and use of the building.

5.2.3 Approach and assessment method

The approach is quantitative and absolute using the assessment methods as shown below.

Table 13: Approach and Assessment Method used

BCA Clause A0.3	BCA Clause A0.5
A Performance Solution must: **(a) comply with the Performance Requirements; or**	**The following Assessment Methods, or any combination of them, can be used to determine a Performance Solution or a Deemed-to-Satisfy Solution complies with the Performance Requirements:**

BCA Clause A0.3	BCA Clause A0.5
(b) be at least equivalent to the Deemed-to-Satisfy Provisions, and be assessed according to one or more of the Assessment Methods.	(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 of the BCA. **(b) Verification methods such as—** (i) the Verification Methods in the BCA; 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

5.2.4 Fire safety design requirements

The fire safety measures listed in Table 8 form the holistic fire safety design for the building's Performance Solutions. The additional fire safety measures specific to this Performance Solution are as follows:

- A fire sprinkler system in accordance with AS2118.1 and BCA Clause E1.5 shall be provided throughout the manufacturing building. The response time index of the sprinklers shall not be greater than 50 $m^{½}s^{½}$.
- A building occupant warning system in accordance with AS1670.1 shall be provided throughout the manufacturing building. Activation of the fire sprinkler system shall activate the building occupant warning system.
- Emergency manual call points in accordance with AS1670.1 shall be provided within the manufacturing building. The manual call points shall be white in colour and designed in accordance with the 'Emergency Warning' functionality of Clause 3.15 of AS1670.1 to activate the building occupant warning system only. These manual call points shall be distributed to the exits from the manufacturing building.

5.2.5 Acceptance criteria

To demonstrate that the design satisfies the BCA Performance Requirements, the analysis must show that occupants are able to evacuate the building safely in the event of a fire and that the conditions for fire service intervention are acceptable.

5.2.5.1 Worst Credible (Base) cases

Available Safe Egress Time (ASET) calculated for the worst credible design fire scenarios must be better than or at least equivalent to the Required Safe Egress Time (RSET) for the worst credible design fire scenarios incorporating a safety factor of 1.5. That is:

$$ASET \geq 1.5 \times RSET$$

5.2.5.2 Sensitivity cases

ASET calculated for the sensitivity and redundancy scenarios must be better or at least equivalent to the RSET for the worst credible redundancy fire scenarios:

$$ASET \geq RSET$$

The tenability criteria for occupant evacuation is in accordance with the IFEG, CIBSE Guide E – Fire Engineering and other relevant fire safety codes / publications. The occupant tenability criteria are set out in Table 14

5.2.5.3 *Redundancy cases*

In a redundancy case the primary exit is blocked, requiring occupants who have traversed to the primary exit to travel instead to an alternative exit, returning to their point of choice first, as required by BCA measurements, defined as $RSET_{(Red.)}$

$$ASET \geq RSET_{(Red.)}$$

5.2.5.4 *Occupant Tenability*

Occupant tenability criteria and acceptability are developed from the [IFEG], which details the acceptable limits for occupation of the modelled space. It is noted that visibility is typically the determining factor for large areas. These limits are shown in Table 14.

Table 14: Occupant tenability criteria [IFEG]

Occupant Tenability Criteria	
Convective heat	Temperature < 60 °C when smoke layer is below 2.1 m
Radiant heat exposure	Radiant flux < 2.5 kW/m^2 at 2.1 m above floor level
Visibility	Illuminated sign visibility > 10 m in open paths and > 5 m when queuing

Visibility shall also be assessed at a 4 m height due to the increased height of the exit signs.

5.2.5.5 *Factor of Safety*

1.5 for worst credible (base) cases and 1 for sensitivity/redundancy cases.

5.2.5.6 *Fire Brigade Intervention*

Fire brigade intervention is considered acceptable so long as the 'Hazardous' intervention conditions from the [AFAC] are not exceeded during 600 seconds of modelling (allowing for sprinkler activation and potential suppression), namely a low level air temperature of below 120 ^{o}C.

5.2.6 Method of analysis

The building includes extended travel distances which generate an extended egress time. The performance based smoke hazard management system includes specified smoke extract rates and increased reservoir sizes which may decrease the Available Safe Egress Time (ASET). The intent of the analysis is therefore to demonstrate that occupants still are expected to be able to evacuate the building or reach the nearest exit before conditions become untenable in the event of a fire. This is done by undertaking an ASET/RSET analysis. The Available Safe Egress Time (ASET) is quantified through Computational Fluid Dynamics (CFD) modelling for a number of fire scenarios.

The required safe egress time (RSET) is a combination of three parameters; the alarm time, the pre-movement time and the travel time.

- Alarm Time – The time between ignition and activation of the smoke detection or sprinkler system.
- Pre-Movement Time – The time taken for occupants to react to an alarm and commence evacuation.
- Travel Time – The time taken for all of the occupants to move to an exit or point of safety.

The detailed description of the RSET calculations are provided in Appendix A.

5.2.7 Hazards

A detailed view of the potential 'special hazard' that the waste material and PEF has been undertaken in Section 4, which details how the hazard of the planned materials for the site have been considered and integrated to this analysis.

The major hazard for occupants is exposure to smoke. Apart from smoke, the other major hazards are radiant and convective heat exposure to Fire Brigade. The aim of the Performance Solution is to ensure occupants have adequate time to evacuate the building prior to the onset of untenable conditions and to provide fire fighters adequate facilities to carry out search and rescue activities and commence firefighting.

Large manufacturing facilities may contain significant fire loads but generally also have a higher than normal ceiling spaces. This brings the challenges to the travel distances, clear smoke layer heights and smoke layer temperature requirements.

Where a fire occurs, the fire can be expected to grow until human intervention or sprinkler activation. The risk to occupants in this fire scenario is the extended travel distances to an exit as well as extended distances between exits is that hot upper level combustion products will build up under the ceiling and may cause untenable conditions in the building prior to occupant evacuation completing. These critical hazards shall be examined in the detailed analysis.

5.2.8 Fire and Smoke Modelling

In order to assess the extended travel distances found within the manufacturing building, CFD modelling is utilised to establish the tenability conditions within the enclosure during an evacuation and assess whether they meet the necessary criteria for both occupants and fire brigade personnel.

5.2.9 Geometry and Spatial Discretisation

In order to model the effects of fire and smoke the buildings geometry must be approximated on a 3-dimensional grid (mesh), which can then be tested under the various fire conditions proposed. Due to the limitations of the model the mesh, and therefore the geometry, is limited to the mesh resolution of the model. For the analysis in this report all models will have a mesh resolution of 0.25 × 0.25 × 0.25 m. As the modelling is designed around the tenability of the manufacturing building exhibiting DtS non-compliant travel distances, only this area is included in the model's domain.

5.2.10 Fire Scenarios and Design Fire Properties

As part of the modelling analysis a number of design fires are tested to better understand the models reaction to different fire scenarios. The core of the analysis is performed under the "worst credible scenario", which is derived from the worst condition considered likely to occur in that space. A number of other fires are considered as "sensitivity" fires in order to perform sensitivity analyses on different aspects of the modelling assessment.

These sensitivity analyses measure the impact on the results of changing one or more key analysis parameters, one of which is the properties of the design fires used.

5.2.10.1 Base Case Fires

Based on the fuel load, fire growth rate and hazard assessment, the base case design fire is assumed to grow at an ultra-fast growth rate in line with the type of fuel load expected. The HRR of the fire is assumed to be controlled (i.e. HRR held level) on the activation of the first array of sprinklers, which is predicted using Alpert's correlation.

5.2.10.2 Sensitivity Fires

The sensitivity studies for the assessments by assuming that the fire is not controlled until the second array of sprinklers are activated. As this is the more conservative scenario, where the sensitivity fires can demonstrate an adequate RSET, it is assumed that the base case fires, being smaller, would also be satisfied.

5.2.10.3 Design Fire Location

Two fire locations are selected as shown in Figure 11. The selection of the fire locations considers the sensitivity of fire and smoke spread and fuel load.

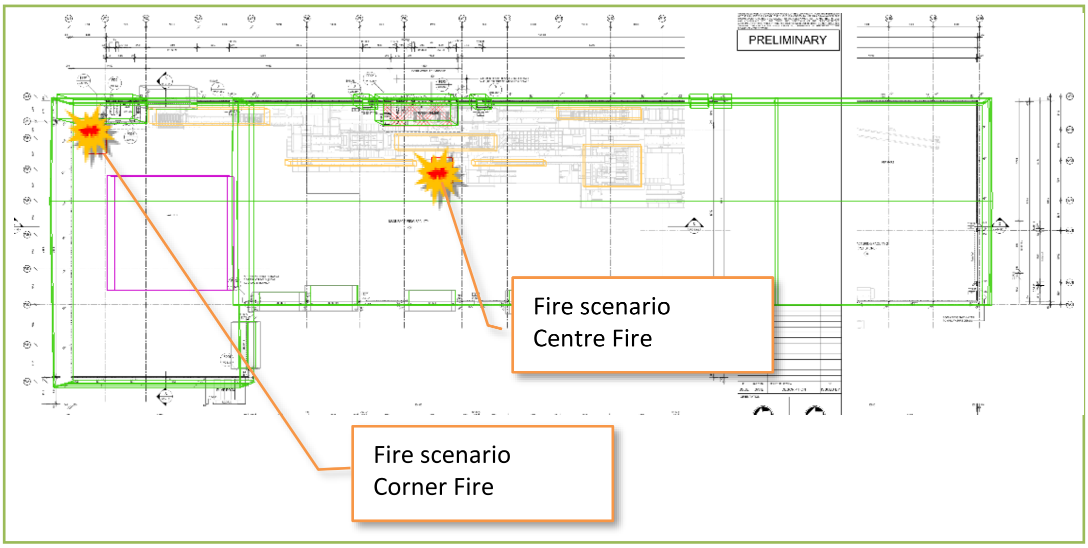


Figure 11: Fire scenario locations

5.2.10.4 Prescribed HRR

Table 15 show the HRRs adopted for the chosen fire scenarios which were derived as described above.

Table 15: Summary of Maximum Heat Release Rate Prescribed in the FDS Input

Descriptor	Growth Rate	Peak HRR	Derivation
Fire scenario Corner (Base case)	Ultra-fast t-squared growth	10,000 kW	Alpert's correlation - first array sprinkler activation
Fire scenario Corner (Sensitivity case)	Ultra-fast t-squared growth	20,000 kW	Alpert's correlation - second array sprinkler activation
Fire scenario Centre (Sensitivity case – Centre)	Ultra-fast t-squared growth	20,000 kW	Alpert's correlation - second array sprinkler activation

NB: The modelling assumes the use of sprinklers with an activation temperature 101°C and RTI of 50 $m^{1/2}s^{1/2}$.

5.2.10.5 Ventilation Conditions

This model includes natural ventilation, in the form of the vehicular roller shutters being open. The roller shutters around the manufacturing building are to be open during operational hours.

5.2.10.6 Other Properties

The script for the Gas Phase Reaction and Miscellaneous is shown below:

```
&REAC ID='POLYURETHANE_REAC',
    FYI='SFPE Handbook, GM27',
    FUEL='REAC_FUEL',
    C=1.0,
    H=1.7,
    O=0.3,
    N=0.08,
    CO_YIELD=0.042,
    SOOT_YIELD=0.1/
```

VISIBILITY_FACTOR=8

The molecular make-up of the gas phase reaction species is taken from the NFPA Handbook, and is a common species for use in soot heavy FDS models. While the molecular makeup somewhat influences the tenability conditions by governing the amount of fuel consumed, the values for SOOT_YIELD, MASS_EXTINCTION_COEFFICIENT, and VISIBILITY FACTOR most directly influencing the modelled tenability conditions. The key (only) resulting parameter from the description of the molecular makeup is the heat of combustion of the fuel. As the design fires in these models are prescribed in terms of the HRR, the heat of combustion determines the amount of fuel consumed and therefore the amount of soot and carbon monoxide released.

SOOT_YIELD (in kg/kg) is the amount of soot released per unit mass of burnt fuel.

CO_YIELD (in kg/kg) is the amount of carbon monoxide released per unit mass of burnt fuel. The value for carbon monoxide yield is taken from the SFPE Handbook [SFPE], which for polyurethane cites values of between 0.031 and 0.051. The value for CO_YIELD (0.042), is taken from the higher end of these values. As cellulosic materials tend to have carbon monoxide yields that are and order of magnitude lower, this value is sufficiently conservative to incorporate both types of materials.

MASS_EXTINCTION_COEFFICIENT is the coefficient which relates the impact of smoke in the air on the intensity of light, i.e. it determines how much each unit mass of soot affects visibility, with a greater value indicating a stronger (worse) impact. The value recommended by the default value for FDS is 8,700 m^2/kg, which is based on the work of Mulholland [SFPE]. The research established the value of 8,700 m^2/kg based on a review of experimental studies, and calculated a 95% confidence interval of ±1,000m^2/kg around this value.

VISIBILITY_FACTOR is a non-dimensional factor that establishes the relationship between the visibility of an object and the mass extinction coefficient. For light reflecting signs the FDS User’s Guide recommends a value of 3, and for light emitting signs the guide recommends a value of 8. These values are obtained directly from the work of Mulholland in the SFPE Handbook, on smoke production properties, who suggests these values are based upon experimental research.

5.2.11 Analysis

5.2.11.1 Time Line Analysis

The fire engineering analysis has been based on ‘Time Line Analysis’. The analysis consists of computational fluid dynamics (CFD) fire and smoke modelling to determine available safe egress times (ASET) within the manufacturing building. Human behaviour and occupant evacuation modelling has also been undertaken to determine the required safe egress times (RSET) from various locations of the building to reach a place of safety. The egress times incorporates the alarm notification times, and the travel times required to travel to a place of safety.

By illustrating that the ASET exceeds the RSET by a reasonable margin, this assessment demonstrates that occupants can safely evacuate from the building and fire brigade personnel enter the building without exposure to hazardous conditions.

5.2.11.2 Required Safe Egress time (RSET)

The RSET is the time taken for the occupants to escape and depends upon the detection time, types of warning systems and range of other factors related to occupant evacuation behaviour and movement. In this report, RSET is split into two consecutive stages: cue time and egress time.

Cue time is the time between ignition and occupant movement. It is recognised that due to a number of factors such as the perceived prevalence of false alarms, social pressure, and curiosity, occupants are unlikely to react immediately upon sounding of an occupant warning system. To account for this, it is assumed that occupants do not begin evacuation until after they have received confirmation of the presence of the fire. Whilst this confirmation may come from a number of sources, for the purposes if this analysis it is assumed that the presence of smoke spreading across the ceiling will provide both visual and olfactory confirmation to occupants. The cue time is therefore taken when sprinkler system activation has occurred and smoke is visible from the entirety of the floorplate. It is expected that after this point all occupants have both heard the occupant warning system and noticed the smoke (by both sight and smell), and therefore will begin movement.

Egress time is the time taken for all occupants to move from their original location to a complete evacuation (i.e. have left the building) once movement has begun. The modelling process to determine this value incorporates both the time taken for occupants to travel to an exit, as well as the congestion time caused by occupants queuing for exits. It is noted that as the building is expected to have a low population, the travel time to an exit is the primary consideration.

The calculated RSET (detection time + pre-movement time + egress time) for both the base case and redundancy case is detailed in Appendix A.5.

The RSET calculated for the base case is: RSET = 325 s

The RSET calculated for the redundancy case is: $RSET_{(Red.)}$ = 415 s

5.2.11.3 Available Safe Egress Time (ASET)

In order to determine the ASET for the building, fire scenarios have been selected which represent the most challenging situations for life safety of occupants and fire brigade intervention and hence the fire hazard subsystems.

The tenability criteria for occupant life safety is based on the SFPE Handbook of Fire Protection Engineering and CIBSE Guide E Fire Engineering [CIBSE], which requires temperature, visibility and toxicity conditions to be maintained so that they do not endanger human life by satisfying either one of the criteria. Untenable conditions for the occupants only apply for hot layer heights that descend below 2 m above the finished floor.

The detailed ASET/RSET analysis through the CFD including the parameters and process are shown in Appendix A and Appendix B and the results are summarised in Table 16.

Table 16: RSET vs ASET

Fire scenario	ASET (s)			RSET (s)	Safety Margin (s)	Safety Factor	Acceptance Criteria Satisfied?
	Smoke Temp > 60 °C	Visibility < 10 m	Heat Flux at Floor > 2.5 kW/m^2				
Corner Fire (Base case – North corner)	>600	>600	>600	325	>275	>1.8	Yes
Corner Fire (Sensitivity case – North corner)	>600	>600	>600	325	>275	>1.8	Yes
Centre Fire (Sensitivity case – Centre)	>600	>600	>600	325	>275	>1.8	Yes
Corner Fire – Redundancy Travel	>600	>600	>600	415	>185	>1.44	Yes

As demonstrated in Table 16, the ASET exceeded the RSET for all scenarios, which indicates that occupants of manufacturing building have been provided with sufficient levels of safety to egress in a fire scenario.

5.2.11.4 Exit Sign Height

The CFD analysis also included slices at 4 m height within the compartment, consistent with the maximum exit sign heights planned. These slices are included in Appendix B, and demonstrate that while occupants are egressing from the building, the exit signs are expected to maintain visibility for the duration of evacuation.

Table 17: RSET vs ASET – Exit sign heights at 4m

Fire scenario	ASET (s)			RSET (s)	Safety Margin (s)	Safety Factor	Acceptance Criteria Satisfied?
	Smoke Temp > 60 °C	Visibility < 10 m at 4 m	Heat Flux at Floor > 2.5 kW/m²				
Corner Fire (Base case – North corner)	>600	>600	>600	325	>275	>1.8	Yes
Corner Fire (Sensitivity case – North corner)	>600	>600*	>600	325	>275	>1.8	Yes
Centre Fire (Sensitivity case – Centre)	>600	>600	>600	325	>275	>1.8	Yes
Corner Fire – Redundancy Travel	>600	>600	>600	415	>185	>1.44	Yes

** It is noted that visibility at 4 m is partially lost near the fire base and north area, though no exits are present on that wall.*

As demonstrated in Table 17, the ASET exceeded the RSET for all scenarios, which indicates that occupants will be able to navigate using the exit signs at the 4 m height for the entirety of their evacuation, and thus has been provided with sufficient levels of safety in a fire scenario.

5.2.11.5 Fire Brigade Intervention

Fire brigade intervention has also been considered, when assessed against the [AFAC]. The modelling performed indicates that temperatures within the compartment do not exceed the Hazardous criteria limit of 120 °C at reaching model steady state, in excess of 600 seconds. This is depicted in Appendix B. Therefore, it is considered that fire brigade intervention has been maintained in the Performance Solution.

5.2.12 Conclusion

The CFD analysis has demonstrated that the expected RSET is below the anticipated ASET for the fire scenarios modelled. When considering relevant safety factors, the RSET has been demonstrated to be less than the ASET in base case, sensitivity and redundancy scenarios, as well for at the 4 m exit sign height, thereby demonstrating that the Performance Solution satisfies Performance Requirements DP4, EP2.2 and EP4.2.

5.3 Solution 3: Office Level 1 Extended Travel

5.3.1 Introduction

On the first floor of the Office building, from the corners of Office 1 and 2 there exits potentially extended travel distances, when accounting for workstation placement in the open plan area. This is depicted below.

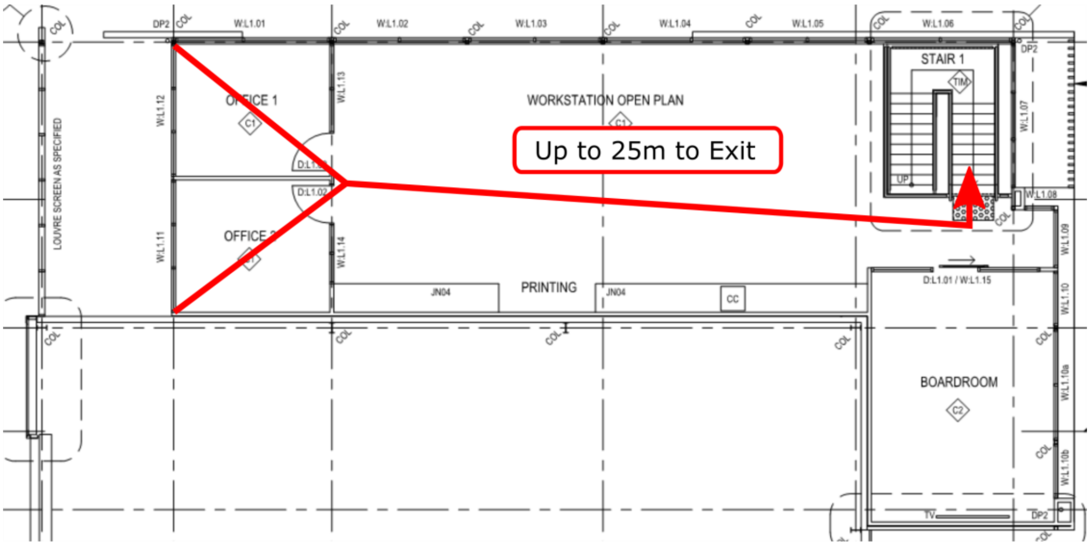


Figure 12: Extended Travel distance in Office Area, First Floor

Table 18 provides a summary of this DtS non-compliance, the relevant BCA DtS Provisions, and the relevant BCA Performance Requirements and IFEG sub-systems.

Table 18: Summary of DtS non-compliance

No	Description of DtS non-compliance	DtS Clause	Performance Requirement	IFEG Sub-systems
3	Travel distances within on the first floor of the office is extended up to 25 m to a single exit, in lieu of 20 m.	D1.4	DP4, EP2.2	E, F

5.3.2 Intent of the BCA

5.3.2.1 BCA Clause D1.4

BCA Clause D1.4 applies specified values to travel distances. The Guide to the BCA states the intent is to '*maximise the safety of occupants by enabling them to be close enough to an exit to safely evacuate'.* For Class 5-9 buildings/areas, the travel distances have been chosen based on the assumption people are awake and therefore able to react to alarm signals. The travel distance is the baseline level of safety expected to be afforded to occupants, which must be demonstrated to be maintained to the degree by the Performance Solution.

5.3.2.2 BCA Performance Requirement DP4

BCA Performance Requirement DP4 relates to the number, dimensions and distribution of exits. In determining the applicability of this Performance Requirement and any Performance Solutions, the analysis must show that occupants can evacuate safely. This is demonstrated through several aspects, including the location of exits, dimensions of exits, characteristics of occupants, and most importantly, the travel distance occupants must travel. Of particular relevance is that as travel distance increases, so does the time it takes for occupants to reach an exit or a place of safety.

5.3.2.3 BCA Performance Requirement EP2.2

BCA Performance Requirement EP2.2 relates to the evacuation routes themselves, ensuring that they must remain tenable. From the Guide to the BCA, '*Occupants must be given time to evacuate before the onset of untenable conditions*.' EP2.2 expands upon the untenable conditions to consider the temperature, visibility and toxicity within the evacuation route, and that the period of evacuation shall be relevant to a number of aspects, including occupant characteristics and travel distances. Therefore, in satisfying EP2.2, it must be demonstrated that occupants shall be provided with tenable conditions during their egress, either in comparison to a Deemed-to-Satisfy design or absolutely.

5.3.3 Approach and assessment method

The approach is qualitative and comparative, using the assessment methods shown below.

Table 19: Approach and Assessment Method used

BCA Clause A0.3	BCA Clause A0.5
A Performance Solution must: (a) comply with the Performance Requirements; or **(b) be at least equivalent to the Deemed-to-Satisfy Provisions,** and be assessed according to one or more of the Assessment Methods.	**The following Assessment Methods, or any combination of them, can be used to determine a Performance Solution or a Deemed-to-Satisfy Solution complies with the Performance Requirements:** (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 of the BCA. (b) Verification methods such as— (i) the Verification Methods in the BCA; 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**

5.3.4 Fire safety design requirements

The fire safety measures listed in Table 8 form the holistic fire safety design for the building's Performance Solutions. The additional fire safety measure specific to this Performance Solution is as follows:

- Two (2) additional ABE type extinguishers, minimum 2.5 kg each, shall be provided on the first floor of the office, in locations shown on Figure 15.

5.3.5 Acceptance criteria

The analysis must demonstrate that occupants are put an equivalent or lower level of risk of entrapment or obstruction prior to exiting from the building, when compared to a DtS compliant design.

5.3.6 Method of analysis

The analysis shall compare the Performance Solution against a DtS compliant design in regards to all aspects of travel via a non-fire isolated stair for exit purposes. In doing so, the analysis shall highlight the level of acceptable risk in a DtS compliant solution, as well as identify where occupant entrapment is most likely to occur. A further qualitative and absolute analysis regarding potential entrapment shall also consider the additional fire safety measure and its effectiveness.

5.3.7 Hazards

The primary hazard in this case stems from the potential for occupants to become trapped by a fire as they egress along a longer pathway than permitted in a DtS compliant design.

For office use areas, the highest areas of fire risk are typically found in kitchen areas. [FRNSW Statistics] indicate that a kitchen use are of an office are responsible for 3-4 times as many fires as office-use areas. The presence of heating elements such as stove tops likely contribute to the increased risk of the kitchen areas over any other, and is consistent across many different classifications of buildings. It is highlighted for this design, the kitchen area is on the ground floor, while the first floor is office use only.

5.3.8 Analysis

The extension of travel distances within the office areas coincide with the use of a non-fire isolated exit. The use of the non-fire isolated exit is permitted as part of a DtS compliant design, which recognises the low height of the office building, small floor plate and therefore relatively low levels of risk to occupants.

The primary consideration when extending travel to a single exit or point of choice is that of entrapment. Because occupants are only afforded a single point of egress, the loss of this pathway at any point may trap the occupant with no alternative pathway. However, when occupants are required to use a non-fire isolated exit as means of egress, it is important to consider their egress pathway as a whole as well.

5.3.8.1 Non-fire isolated stair travel

The level of risk accepted within the BCA when utilising a non-fire isolated stair shall be considered. A DtS compliant design per Clause D1.9 permits total travel via a non-fire isolated stairway to be less than 80 m total, prior to discharge to a road or open space. Further, a discharge from a non-fire isolated stairway is permitted up to 20 m of travel internal to the building before discharging to a road or open space. The following table considers a DtS compliant design against the Performance solution.

Table 20: DtS Compliant Design and Performance Solution Comparison

Travel	DtS Compliant Design	Performance Solution	Comparison
First Floor – To nearest exit	Up to 20 m	Up to 25 m	**Worse in Performance Solution**
Non-Fire isolated stairs	Connects 2 storeys (no sprinkler protection)	Connects 2 storeys, approximately 10 m travel	**Equivalent**
Stair discharge to final exit	Up to 20 m	Up to 5 m	**Better in Performance Solution**
Total travel to exit	Up to 80 m	Approximately 40 m	**Better in Performance Solution**

This comparison is also depicted below in Figure 13, with the DtS compliant design diagram from the Guide to the BCA.

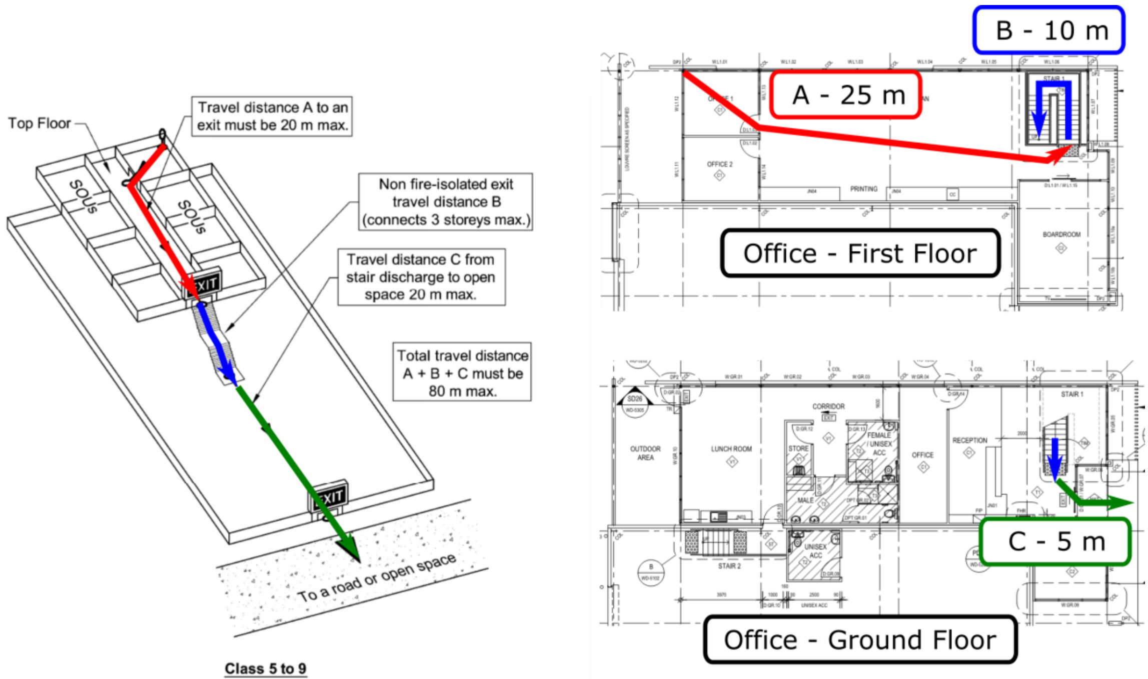


Figure 13: Comparison to DtS Compliant Design (per Guide to the BCA drawing)

It is noted that the DtS compliant design does not require separate pathways from the discharge of the stair, therefore 80 m in the DtS compliant design may be along a single pathway for its entirety, whereby obstruction or entrapment could occur at any point. The level or risk acceptable in a DtS compliant design is therefore much higher than in the Performance Solution, which limits the total travel via the non-fire isolated stairs to approximately 40 m.

This lack of restriction on what area the non-fire isolated stair discharges into is also a critical risk consideration. For the Performance Solution, the extended travel occurs in the office work area, and the non-fire isolated stair discharges directly beside the final egress door. A DtS compliant design with up to 20 m of travel can pass across a number of different areas within the building before discharging.

A DtS compliant design in this case, for the same office building, could omit Office 1 & 2 to reduce travel from the first floor, as well as omit the front door as an egress door, given the small floor plate. Occupants of the first floor would then be provided with 20 m of travel on the first floor, 10 m of travel via non-fire isolated stairs, and a further 20 m of travel to reach the rear door, for a DtS compliant 50 m of total travel. However, from a risk perspective, the final 10 m of the egress is via the Lunch room area. [FRNSW Statistics] from 2006/2007 indicate that between office areas and kitchen areas, kitchen areas are 3 times more likely to be the source of fire ignition, representing a greater risk of fire to occupants than the office area on the first floor, and therefore also the highest entrapment potential.

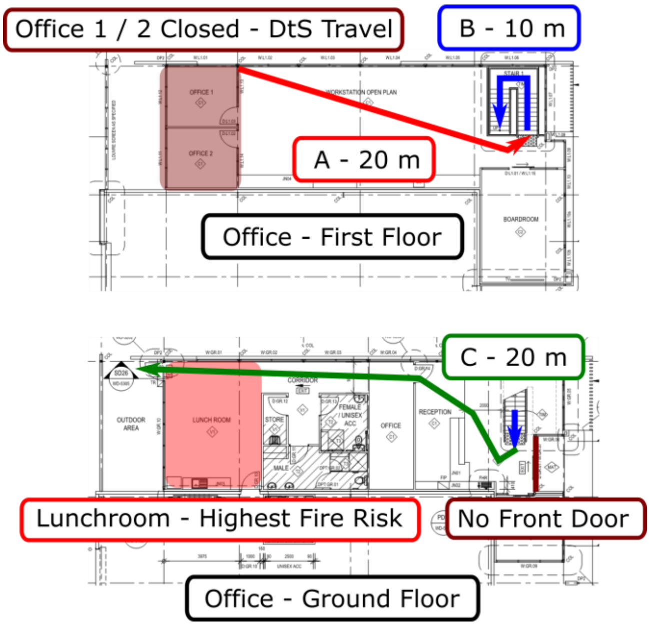


Figure 14: DtS compliant design via Lunchroom

The Performance Solution, in providing egress via the front doors after discharging from the non-fire isolated stairs, significantly reduces the risk of entrapment to occupants once they reach the ground floor. When considered from a complete egress perspective, rather than in isolation of the first floor alone, the Performance Solution represents a lower risk to occupant entrapment and exposure than comparable DtS compliant designs.

5.3.8.2 Additional Safety Considerations

While the analysis has demonstrated that the extended travel of the first floor offices is not expected to increase the risk to occupants when looking at the entire exit pathway, the risk of entrapment along the additional 5 m is nonetheless further considered as part of a robust analysis. Occupant entrapment can occur when occupants are not aware of a fire during its incipient phases, which then grows sufficiently large to block movement along a path prior to occupants egressing past. In this case, while unlikely that a fire will grow unnoticed for long given the open plan environment of the office, an additional method of fire protection will be provided to assist in initial fire suppression activities.

As the office building is provided with fire hose reel coverage, there is no DtS requirement for fire extinguishers to be provided to the office areas. The performance solution shall therefore provide two (2) additional ABE type extinguishers, at minimum 2.5 kg each to the floor plate, to further enable occupants to undertake initial fire suppression along their route of travel. The fire extinguishers are proposed to be placed in the following locations on the First Floor, per Figure 15.

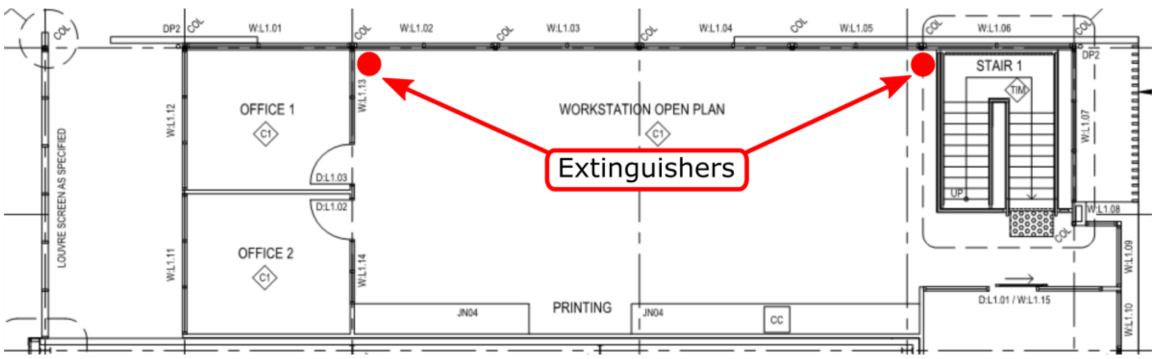


Figure 15: Indicative Extinguisher Placement

The placement of the two extinguishers at either end of the open plan area enable occupants from either side of the room to intervene in a fire scenario, if necessary. While the open plan area is not considered one of high risk, as discussed in Section 5.3.7 the provision of two extinguishers lends further support to occupants being able to avoid entrapment situations by providing an early method of fire suppression.

5.3.9 Conclusion

The analysis has demonstrated that the risk of occupant entrapment prior to reaching a road or open space is comparable in the Performance Solution to a DtS compliant design. Further, additional fire safety measures have been provided to the first floor, and in doing so, Performance Requirements DP4 and EP2.2 have been met.

5.4 Solution 4: Sliding Doors to Offices

5.4.1 Introduction

The primary entry doors to the office building are sliding doors, which also function as an egress point for occupants. As a security measure, the doors are proposed not to fail open upon alarm or power failure. The door location is depicted below.

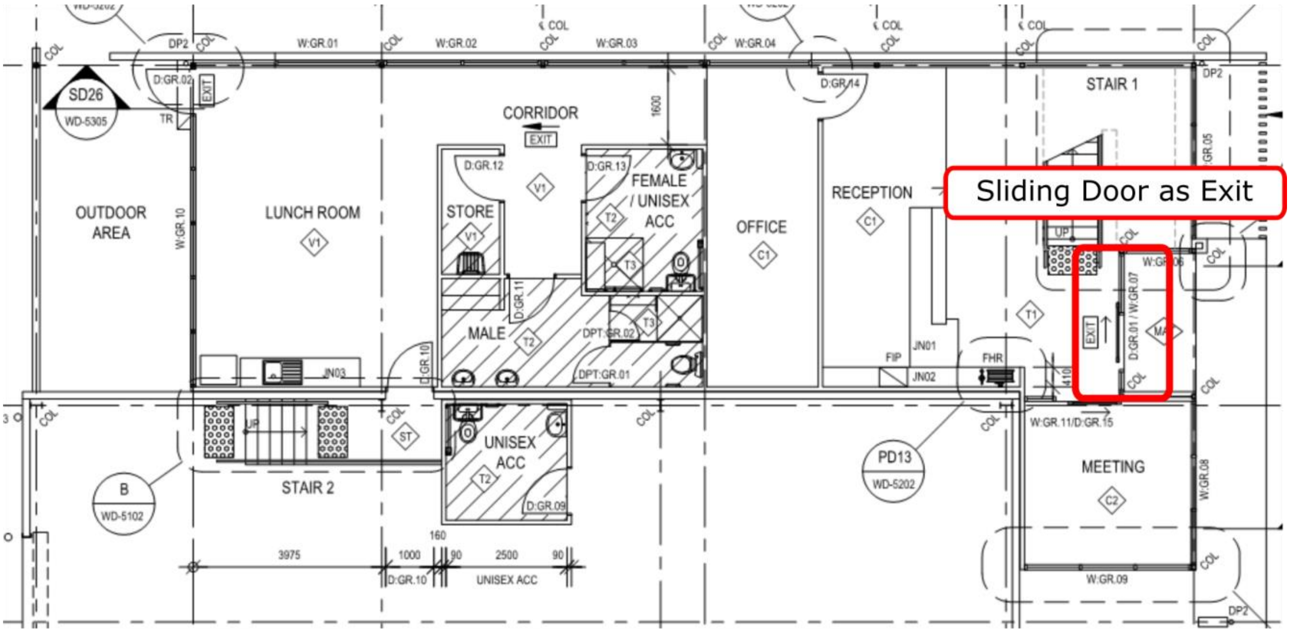


Figure 16: Sliding Door in Office

Table 21 provides a summary of this Solution, the relevant BCA DtS Provisions, which are affected, and the relevant BCA Performance Requirements and IFEG sub-systems.

Table 21: Summary of DtS Non-Compliance

No	Description of DtS non-compliance	DtS Clause	Performance Requirement	IFEG Sub-systems
4	The sliding doors to the office areas shall not meet the requirement of automatically failing open upon alarm or power failure.	D2.19	DP2	E, F

5.4.2 Intent of the BCA

5.4.2.1 BCA Clause D2.19

BCA Clause D2.19 defines the requirements of doors and doorways, as well as placing restrictions on the type of door and their use as exits. Specific in this case to sliding doors, the use of sliding doors place requirements on opening to a road or open space as well as being operable by under force, and if automatic opening, open upon fire trip or power failure. The rationale for this is that the doors are to minimise the risk of obstructing occupant evacuation, regardless of their operation (i.e. swinging, tilt-up, sliding, etc.).

5.4.2.2 BCA Performance Requirement DP2

BCA Performance Requirement DP2 details how people move to and within a building, which in particular in this case applies to doors being installed to avoid the risk of occupants being trapped or having the egress impeded. Therefore, the Performance Solution must address the potential for entrapment or impediment caused by the DtS non-compliance.

5.4.3 Approach and assessment method

The approach is qualitative and absolute using the assessment methods as shown below.

Table 22: Approach and Assessment Method used

BCA Clause A0.3	BCA Clause A0.5
A Performance Solution must: **(a) comply with the Performance Requirements; or** (b) be at least equivalent to the Deemed-to-Satisfy Provisions, and be assessed according to one or more of the Assessment Methods.	**The following Assessment Methods, or any combination of them, can be used to determine a Performance Solution or a Deemed-to-Satisfy Solution complies with the Performance Requirements:** (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 of the BCA. **(b) Verification methods such as—** (i) the Verification Methods in the BCA; 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

5.4.4 Fire safety design requirements

The fire safety measures listed in Table 8 form the holistic fire safety design for the building's Performance Solutions. The additional fire safety measures specific to this Performance Solution are as follows:

- The sliding doors are to meet all other requirements of Clause D2.19 for serving as a required exit. That is:
  - The doors are able to be opened manually under a force of not more than 110 N if there is a malfunction or failure of the power source.
  - The following additional requirements are to be provided to each sliding door:
    - An emergency push button shall be located adjacent to each sliding door to operate the door. The emergency push button operation of the door shall still operate in the event of primary power failure (e.g. it may be on essential power or battery back-up to enable occupants to escape in the event of a fire).
    - The push button shall be located adjacent the sliding door and between 900 – 1100 mm above finished floor level.
    - The push button shall be provided with signage highlighting the following in capital letters not less than 20 mm high in a colour contrasting with the background:
      PUSH TO EXIT
    - Where a battery backup is supplied it shall have a local audible alarm to alert building management when the battery is depleted.
    - The battery backup shall have a standby time of 24 hours.

5.4.5 Acceptance criteria

The assessment must demonstrate that the changed door operation conditions are unlikely to result in entrapment for occupants and sufficient egress is available to the occupants.

5.4.6 Method of analysis

A qualitative analysis shall assess the building function and occupant characteristics which shall play a relevant role in the evacuation process.

5.4.7 Hazards

For the change to a sliding door operation which does not automatically open, the key increased risks are as follows:

- The increased operational time of door hardware means occupants may be exposed to hazards for a longer period of time, allowing conditions such as radiant heat and toxic gas levels to greater affect an individual.
- Occupants may be delayed when waiting for the sliding doors to open which means that the fire may develop further during the time an occupant makes their escape, meaning that conditions in the space at the time of evacuation may be worse.
- The delayed movement time increases the opportunity of blockages occurring along an occupants egress path and, especially combined with the effects of prolonged exposure or decreased visibility conditions, an increased risk of occupants becoming disoriented.

5.4.8 Analysis

The BCA requires that the provision of a sliding door as an egress pathway must lead directly to an open space, is able to be opened manually under a force of not more than 110 N if there is a malfunction, and that if power operated, must open automatically in a power failure or fire/smoke alarm activation.

The only portion of the clauses that will not be met are the operation during power failure to open. As the office/workshop building does not require prescriptive sprinklers or smoke detection, there is no scenario which would activate a fire/smoke alarm from within the office/workshop building. Therefore, the primary addressable concern is during power failure scenarios. Fire scenarios shall also be considered supplementary to the discussion.

During the occupied/operational hours, in the event of a power failure, the sliding doors would remain shut in the Performance Solution. In a DtS compliant design, the doors would open automatically, therefore consideration must be given to any delay created by this DtS non-compliance. If power were to fail during occupied/operational hours, it is therefore assumed that the door will become manual opening only.

Door use can be described as a process which includes six subtasks in order as follows [Steinfeld]:

1. Perceiving and understanding door operation
2. Altering gait, adjusting body posture and manoeuvring within reach
3. Reaching and grasping handles, switches or locks
4. Applying force to overcome resistance of handles, switches or locks
5. Applying force to overcome resistance of the door, mechanical door closers and pressure differentials
6. Passing through the doorway, including making adjustments in posture and continuing to apply force

The provision of a manually operable sliding door is not in itself a DtS non-compliance, as unpowered sliding doors are permitted so long as they open directly to a road or open space and can be opened manually with a force of 110 N. Therefore, it is considered the action itself of opening a sliding door is not considered to be onerous by the BCA, but that a change of operation has occurred that occupants must adapt to. If occupants enters a building with an automatic sliding door, the perception of operation would be of an automatic design in both directions. Therefore, the expectation would be of automatic opening to egress as well, and if this were not the case, sufficient signage and warning must be provided to assist in determining an alternative method of operation.

Within the Performance Solution it is considered only subtasks (1) perception and understanding of the door operation; and (2) body posture for approach are adversely affected by the provision of not automatically opening the sliding doors and instead requiring push button activation. Items 3 to 6 are considered to be improved or equivalent when compared to a compliant design, given the lack of handles/locks required. Therefore, provided subtasks 1 and 2 are addressed, the design shall be equivalent to a DtS design. All other subtasks are considered to be equivalent in nature to that of a DtS doorway opening.

5.4.8.1 Addressing Perception and Understanding of Door Operation

The abilities of the person, the ambient environment and the social context play a major role in successful completion of this subtask. These factors can affect the perception and understanding of door use as well as the level of stress involved in the task. Stress may be related to limitations in ability, difficult environmental conditions such as low levels of illumination or social pressures such as a crowd of hurrying people. In that respect perception and understanding of door operation can be improved through the implementation of text and visual images, as well as repetitive use of the door.

The Push button exit is to be provided with visible signage, indicating the operation at the door for staff. 'Push to Exit' is common wording which is considered to be readily acknowledgeable and gives clear, simple direction as to the operation of the button. This is intensified by the expected low occupant load and high degree of familiarity with the layout and door location that can be expected with the small office environment.

5.4.8.2 Addressing gait and body adjustment

Gait, body posture and manoeuvrability are influenced by the activation of the sliding door. As opposed to continuing with forward momentum an occupant is forced to stop, align their body to press the button, wait for the doors to open and then pass through. This is most important when there are large numbers of people as other occupants might push against each other causing congestion and crushing at the opening.

Overall, the inclusion of the signage, combined with staff familiarisation and low occupant numbers is considered to be a suitable control to increase occupant perception and understanding of the door use and alteration of gait and body positioning so as to open the sliding door.

5.4.8.3 Consideration of the BCA Requirements

A power failure scenario may coincide with a fire scenario, however there are many instances where these two cases do not intersect. Power can be lost due to numerous reasons, and if occurring during unstaffed hours, can pose a security risk to the building itself if the doors were to be forced open when nobody else was in the building.

During occupied hours and normal operation, egress from the building would not be expected to be delayed as the automatic sliding door would operate under normal conditions (i.e. sensing an approaching body). It is only in a fire scenario which also caused, or coincided with, a power failure, that any deviation from a DtS compliant design would be noted. However, as described in the analysis above, this delay will be minimised by the addition of the Push to Exit button and associated signage.

Outside of occupied hours, the building being unoccupied renders the consideration of the doors for egress as moot, and highlights the utility of the Performance Solution design from a security perspective. With no occupants to egress, the function of the door not opening puts no occupants at risk, and allows the building to maintain be maintained as secure.

5.4.9 Conclusion

This fire engineering assessment has demonstrated that the changed door operation conditions is unlikely to result in an increase in risk to the occupants. The low occupant numbers, high familiarity and push button activation of the door is expected to suitably reduce the hazard to occupants. This demonstrates that the provided egress solution is sufficient to satisfy the Performance Requirements DP2 and DP4.

6 Key Assumptions and Limitations

- This report is consistent with the fire safety provisions, objectives and limitations of the Building Code of Australia (BCA):

    - We have been informed that building features not part of a Performance Solution will comply with the Deemed to Satisfy provisions of the BCA.
    - This report excludes the analysis and design of fires including incendiary ones involving accelerants, explosives and/or multiple ignition sources, or acts of terrorism.
    - The concepts outlined in this report assume a complete and operational building, and do not address protection of the building during construction, renovation or demolition.
    - Egress and fire safety provisions for persons with disabilities including compliance with the Disability Discrimination Act (DDA) were considered to the same degree as the BCA.
    - Unless stated otherwise, protection of property (other than adjoining property), business interruption or losses, personal or moral obligations of the owner/occupier, reputation, environmental impacts, broader community issues, amenity or non-fire related matters in the building such as health, security, energy efficiency, and occupational health & safety or the re-installation and costs associated with any damages from fire are specifically excluded from this analysis.
    - All essential equipment services and strategies will be maintained, to the operational capacity to which they were designed, installed, commissioned and certified, in accordance with the manufacturer's instructions. Therefore, all essential equipment services and strategies discussed within this report are assumed to function correctly during a fire situation.

- This report is not a compliance or conformance audit for any fire safety system. For example, operational checks of fire safety equipment, verification of construction techniques, fire resistance levels or the witnessing of fire drills or exercises are specifically excluded from the scope of this report.
- The recommendations in this report are based on information provided by others as listed in Section 1.6. Olsson Fire & Risk has not verified the accuracy and/or completeness of this information.
- The recommendations, data and methodology apply to the subject building and must not be utilised for any other purpose. Any modifications or changes to the building, fire safety management system, or building usage from that described in this report may invalidate the findings, necessitating a re-assessment.

Appendix A CFD Fire and Smoke Modelling

A.1 Introduction

In order to evaluate the outcomes of different fire scenarios for the deterministic assessment, the time of onset of untenable condition is to be calculated.

A.2 Fire Growth & Development

The most commonly used models of fire growth are the t^2 growth curves, as described in the Fire Safety Standard [NFPA 92]. [PD 7974 Part 1] provides guidance on the characteristic fire growth rate for different types of occupancies. For an industrial environment it recommends an ultra-fast-t^2 growth rate. Refer to Figure 17 and Figure 18.

Building use	Fire growth rate
Picture gallery	Slow
Dwelling	Medium
Office	Medium
Hotel reception	Medium
Hotel bedroom	Medium
Shop	Fast
Industrial storage or plant room	Ultra-fast

NOTE *Limits.* The characteristic fire growth rates given in Table 2 should be used for general design purposes for different types of occupancies. For multiple use buildings, the faster growth rate should be taken.

Figure 17: Table 3 – Design Fire Growth Rates (PD7974-1-2003)

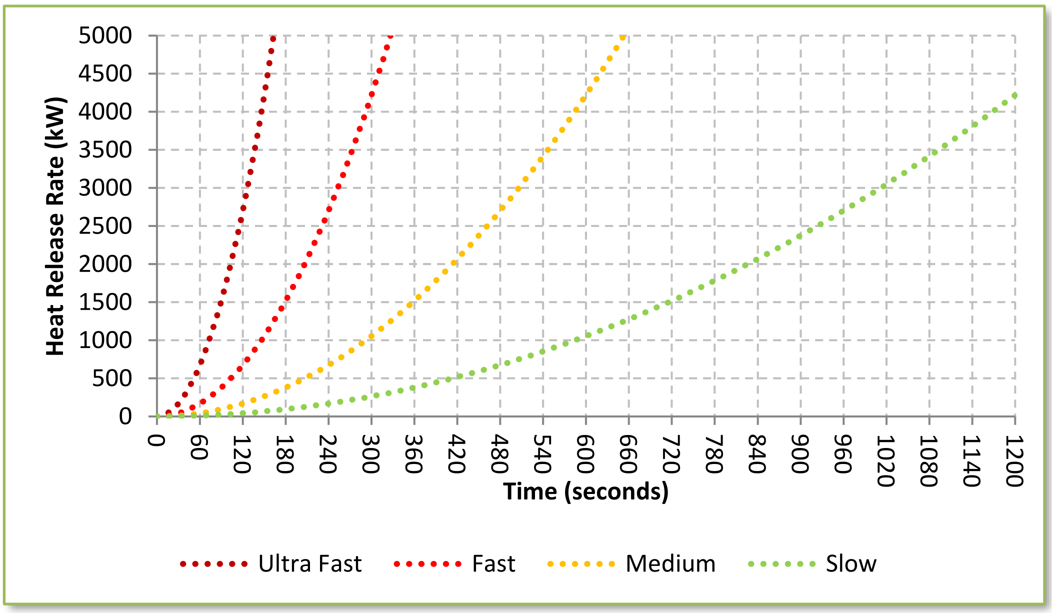


Figure 18: T-Squared Fire Growth Development

The building is to be provided with an automatic fire sprinkler system in accordance with AS 2118.1. Sprinkler activation temperatures are expected to be no greater than 101 °C and having a Response Time Index (RTI) of not greater than 50 (ms)½. Even though the sprinkler system is likely to extinguish or mitigate the fire, in this analysis it was assumed that the HRR remains constant at the time to sprinkler activation which is representative of a shielded fire where total suppression may not be attained.

Statistics from the National Fire Protection Association (NFPA) [Hall Jr.] provides recorded statistics on buildings fitted with automatic fire sprinkler systems between the years 2003-2007 in 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 91% 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 system in Australia and New Zealand is generally considered significantly higher than in the US as researched by [Bukowski].

A sensitivity scenario will also be evaluated. The sensitivity scenario was based on the assumption that the first row of sprinklers most adjacent to the fire fails to activated, and the fire is therefore controlled at the time when the second row of sprinkler heads are expected to activate.

A.3 Fire and Smoke Modelling

A.3.1. General

Fire and smoke modelling analysis will be undertaken using the Computational Fluid Dynamics (CFD) computer program Fire Dynamics Simulator (FDS) developed by the US National Institute of Standards and Technology (NIST) to simulate thermal and mass flow in a building.

FDS is a field model, based on the approach of Large Eddy Simulation technique, where transport of mass, momentum and energy from fire induced flows are solved numerically with a large number of 3-dimensional cells representing the physical space. This approach is considered suitable to simulate the flow of heat and smoke through a large area. FDS computes the temperature, density, pressure, velocity and chemical composition within each numerical grid cell at each discrete time step. Smokeview is a companion program that produces images and animations of the results. Because the model was originally designed to analyse industrial-scale fires, it can be used reliably when the heat release rate (HRR) of the fire is specified and the transport of heat and exhaust products is the principal aim of the simulation.

A.3.2. Grid size

The most important decision made by a model user is the size of the numerical grid. In general, the smaller the numerical grid, the better the numerical solution to the equations. FDS is second-order accurate in space and time, meaning that halving the grid cell size will decrease the discretization error in the governing equations by a factor of 4 [NIST 1019-5]. Because of the non-linearity of the equations, the decrease in discretization error does not necessarily translate into a comparable decrease in the error of a given FDS output quantity. To find out what effect a finer grid has on the solution, a grid sensitivity study in which the numerical grid is systematically refined until the output quantities do not change appreciably with each refinement. Of course, with each halving of the grid cell size, the time required for the simulation increases. In the end, a compromise is struck between model accuracy and computer capacity.

In the FDS User Guide, it notes that *"in general, you should build an FDS input file using a relatively coarse mesh, and then gradually refine the mesh until you do not see appreciable differences in your results."* It highlights that for simulations involving buoyant plumes, a measure of how well the flow field is resolved is given by the non-dimensional expression D^*/δ_x, where D* is a characteristic fire diameter.

$$D^* = \left(\frac{Q}{\rho_\infty c_p T_\infty \sqrt{g}}\right)^{\frac{2}{5}}$$

Where:

Q = heat release rate (kW)
p_∞ = ambient density (kg/m3) = 1.2 kg/m^3
c_p = ambient specific heat (kJ/kg.K) = 1.02 kJ/kg.K
T_∞= ambient temperature (K) = 297 K
g = acceleration due to gravity = 9.8 (m/s^2)

And δx is the nominal size of a mesh cell. The greater the number of cells spread across the fire, the better the resolution of the calculation. However, this comes with a price… being the computational time required for each simulation. For differing fire sizes, there is a measured approach required to the correct adoption of cell size. The FDS user guide gives reference to previous studies for the U.S. Nuclear Regulatory Commission, the D^*/δ_x values ranged from 4 to 16.

		Fire Size (kW)											
	Grid Size (δx)	600	800	1200	1600	1750	2000	2500	5000	10000	16000	20000	40000
D*	0.6	1.3	1.5	1.7	1.9	2.0	2.1	2.3	3.0	4.0	4.8	5.3	7.0
D*	0.5	1.6	1.8	2.1	2.3	2.4	2.5	2.8	3.6	4.8	5.8	6.4	8.4
D*	0.4	2.0	2.2	2.6	2.9	3.0	3.2	3.5	4.6	6.0	7.3	7.9	10.5
D*	0.3	2.6	2.9	3.4	3.9	4.0	4.2	4.6	6.1	8.0	9.7	10.6	14.0
D*	0.25	3.1	3.5	4.1	4.6	4.8	5.1	5.5	7.3	9.6	11.6	12.7	16.8
D*	0.2	3.9	4.4	5.2	5.8	6.0	6.3	6.9	9.1	12.0	14.5	15.9	21.0
D*	0.15	5.2	5.8	6.9	7.7	8.0	8.4	9.2	12.2	16.1	19.4	21.2	27.9

A.3.3. Sprinkler operation

FDS includes a sprinkler spray module which is intended to model the cooling effect of a sprinkler spray to a fire plume. This requires the input of specific parameters which can generally only be determined by real scale fire testing, or may lead to inaccuracies in thermal predictions (higher smoke layer temperatures than would be expected in reality). To manage this deficiency, fire suppression scenarios will not be considered, such that the analysis will use a capped fire size on sprinkler activation (fire controlled) as discussed above. This will result in higher smoke layer temperatures. This represents a robust design approach to the predictions as temperature is a tenability limit.

A.3.4. Additional considerations in the fire modelling

The operation of any systems such as toilet exhaust and cooling systems etc. will not be included in the analysis due to limitations in the modelling and a lack of readily available data.

A.4 Fire and Smoke Modelling Parameters

The combustion process modelled is dependent on the fuel type as it governs oxygen consumption and heat release rate. FDS uses the smoke yield parameter for the generation of smoke within the simulation (mass of smoke produced / mass of fuel burnt).

The CFD modelling undertaken will be based on the following parameters:

- Smoke yield for wood product is typically low; less than 0.01 g/g for fibreboard and 0.001 g/g for hardboard. Plastic materials, however, have a wider range from less than 0.01 g/g to around 0.1 g/g [SFPE]**.**
- In view of the impractical nature of defining precisely the materials involved in a fire, and to allow for a range in material, a soot yield at the higher end of the range will be assigned to the fuel, being 0.1 g/g.
- To account for the wide range of materials forming part of the fuel load, and due to the difficulty in assigning multiple combustion reactions relating to the different materials, polyurethane will be used as the fuel source for the combustion model and will therefore be taken as representative of the material forming the fuel load for the FDS model.

Table 23: Input parameters used for FDS modelling

Parameter	Value
Soot yield	0.1 (polyurethane combustion reaction)
Ambient Temperature	20 °C
Grid Size	0.25 m
Visibility	The visibility constant for illuminating signs i.e. C = 8 (considered appropriate for a compliant AS 2293.1 designed system, where larger signs are required if spacing exceeds 24 m for standard sized signage)
D^*/δ_x value	7

The visibility factor used in the analysis shall be considered specifically for the target (i.e. whether the target is light emitting, such as an illuminated sign; or light reflecting, such as a non-illuminated sign).

A.5 ASET/RSET verification

To consider all extended travel distances it was assumed that occupants would egress from the furthest point within the building to the nearest exit. As a redundancy the exit would be unavailable when they approach it so occupants would have to egress to an alternative exit.

A.5.1. Life Safety

The acceptance criteria set out in Section 5.2.5 was used in determining the performance of the proposed solution.

A.5.2. Calculation of Available Safe Egress Time (ASET)

In the event of a fire in the building, the occupants will need sufficient time to evacuate the building. This assessment uses the computational fluid dynamics (CFD) computer model FDS6 to predict the time during which tenable conditions are likely to be maintained in the egress routes as examined in each design fire scenarios. This provides detailed feedback and results for the calculation of the Available Safe Egress Time (ASET).

A.5.3. Calculation of Required Safe Egress Time (RSET)

Reference is made to the [PD7974-6] for the basis of determining the Required Safe Escape Time (RSET). The exception to this method is that the first occupant starting evacuation is assumed to be present at the exit door as opposed to the method also presented in [PD7974-6] where the first occupant is located at the furthest point of the area.

The RSET is determined based on the time it takes from fire initiation until occupants reach a place of relative safety. The travel time is defined as the time for all occupants to reach a place of safety from their point of origin. In the first instance evacuation will be modelled using hydraulic flow calculations based on first principles. The analysis predicts the total evacuation time (or RSET) for the building, i.e. the time all occupants have left the building and entered the road or open space.

The components of the RSET can be broken down as follows:

$$t_{esc} = t_{alm} + t_{pre} + t_{flow}$$

Where;

t_{esc} = *the escape time*
t_{alm} = *the alarm time*
t_{pre} = *the pre-movement time*
t_{flow} = *the flow time*

The RSET is measured from the same point of origin as the fire, that is, from the time of effective ignition. The calculated RSET is the sum of times incurred during the following three stages of the evacuation process, as outlined:

- *Alarm time* – time taken from effective ignition to the receipt of an alarm (cue) by the occupants regarding the presence of a fire. In open plan areas occupants can also receive a cue upon development of a visible smoke layer under the ceiling.
- *Response (pre-movement) time* – time which extends from the alarm or cue to the time when occupants decide to evacuate. The degree of training and familiarity with the surroundings, as well as the general nature of the population, has an impact on the response time, together with the type of cue received. This period covers the time for occupants to assimilate the cue, resolve any ambiguity, undertake pre-evacuation actions and commence evacuation.
- *Flow time* – occupant evacuation time, which can be calculated on the basis of human walking speeds affected by crowding.

Users specify the parameters used for evacuation calculation, i.e. number of people, maximum travel speed, response time, etc. The building is to be assessed with the maximum number of occupants as calculated using table D1.13 in the BCA which in the case of this building is extremely conservative however will cater for unusually high level of occupancy i.e. training etc.

Where occupants are shown to be able to evacuate safely as per the above acceptance criteria, the Performance Requirements of the BCA are met.

Alarm Time

The activation of the building's BOWS system, i.e. alarm is considered to occur from the sprinkler system or alternatively through visual / olfactory senses and activation of a break-glass alarm.

Alarm time for the occupants in the direct vicinity of the fire location is considered to occur when the BOWS has activated. This is a conservative approach as olfactory, visual and aural cues which will be available to the occupants will be ignored.

The sprinkler activation time analysis was calculated using Alpert's correlation and was used in the RSET analysis. Sprinkler activation time for first row sprinkler activation is estimated at 219 seconds, which was conservatively assumed to be the furthest point away from a fire base as well as at the maximum height differential possible.

Following the completion of the CFD modelling, the alarm time was adjusted downwards to be 145 seconds, which corresponds to smoke being visible across the compartment in the corner fire scenario. The centre fire had smoke becoming visible across the compartment earlier, therefore the later (145 s) time was used for conservatism. It is considered that the considerable smoke spread, along with the open nature of the compartment, would also initiate an alarm for occupants. The pre-movement time has been maintained however, to allow for occupant investigation rather than direct egress.

Pre-movement time

People engage in various activities prior to evacuating. The time taken to perform these activities is referred to as pre-movement time. The pre-movement activities may include investigation, assessing danger, warning others, collecting belongings, seeking assistance etc. Pre-movement time typically applies only to areas remote from the room of fire origin where they may receive only a single cue to the presence of a fire and where those cues do not present an immediate threat to their health and safety. An example is where an occupant remote from the fire origin may smell smoke however would be unsure of its origin and may take investigative action or rationalise that it is 'normal'.

Pre-movement behaviour is a complex cognitive thinking process. Behaviour in fires can best be understood as a logical attempt to deal with a complex, rapidly changing situation where minimal information for action is available. In assessing the likely response of the occupants, the issue of pre-movement time must be addressed. In the case of occupants who are awake and in the vicinity of the fire, the decision to evacuate is likely to be a function of the perceived threat associated with the fire. If the fire is not perceived as threatening, then the occupants may decide not to evacuate. However, if the opposite is true, evacuation will begin almost at once. It is assumed that most of the occupants will associate flaming fires and black smoke with a threatening situation. Thus, in undertaking calculations of evacuation, this can be assumed to commence once a threat is perceived.

In the situation where the occupants are intimate with the development of the fire (area of fire origin), it is reasonable to suggest that occupant avoidance will be immediate, as they will be presented with multiple fire cues and would include:

- Visual - smoke and flames
- Tactile - heat radiated and convection from fire
- Audible - sound generated by burning materials
- Olfactory - smell of smoke and other combustion products

The pre-movement time depends primarily upon the ***building complexity***, the ***alarm type***, ***fire safety management level***, and ***design behavioral scenario category***. Although, it is possible to make an adequate estimation of evacuation times for most situations by considering two main criteria, the pre-movement times of the first few occupants in an enclosure to move (pre-movement time of the 1st percentile of occupants) and the pre-movement times of the last few occupants to move (99th percentile of occupants). However, data on pre-movement time distributions for different behavioral scenarios are currently limited. Some measured distributions exist with suggested default values for pre-movement time 1st and 99th percentiles for different design behavioral scenarios.

However where secondary cues exist, such as significant smoke spread in the occupied enclosure, this is considered to reinforce the threat indicated by the audible alarm and encourage a more rapid response from occupants. Where both the alarm and smoke are present, the pre-movement time will be reduced to zero or the time difference between the alarm and second cue.

Within the analysis it is identified that reliance is placed on both the visual cue following initial alarm and the likelihood that occupants will be provided with cues from other occupants in close proximity to the fire. The SFPE indicates that in over 74% of fires the combination of alarms, visible smoke and indicators from other occupants when a fire threat was acknowledged led to a heightened awareness and supports the use of these cues in this instance.

Building complexity:

The manufacturing building, being simple in layout, without any complex geometry, the complexity of the building as defined in PD7974: Part 6 is B1.

Alarm Type:

It is proposed that the type of alarm system would be that of A3, as despite automatic (sprinkler) detection throughout the building, the activation may be delayed or localised due to the noise of the manufacturing building.

Fire Safety Management:

PD7974: Part 6 states that an M2 fire safety management system is more conservative than an M1 fire safety management system. Despite the building having evacuation testing and fire safety management procedures in place, the M2 designation is selected to provide a more conservative assessment.

Design behavioural scenario:

The design behavioural scenario for the building will be "A" based on PD7974: Part 6 that represents the behaviour of awake, familiar and low density occupants, consistent with an office or industrial space.

Recommended pre-movement times:

Based on the various system levels, PD7974: Part 6 recommends a pre-movement time of 1 minute for the first occupants (1st percentile), with the remaining occupants (99th percentile) having a pre-movement time of 2 minutes.

Therefore, the pre-movement time in the fire scenarios is estimated to be t_{pre}= 120 s.

Travel and Flow time

Travel time is the time taken for all of the occupants to exit the building after they begin moving. There are two components to this: travel time, and congestion time. Travel time is the longest time taken for an occupant to move from their position to their final exit door. Congestion time is the time taken for all of the occupants to move through the available doors, as the total width of exits limits the rate at which occupants can leave the building. In order to account for the fact that both of these actions happen simultaneously (i.e. the furthest occupant is travelling while the other occupants are moving through the doors) only the highest of these values is taken as the total egress time.

Empirical studies from the [SFPE] and [CIBSE] have shown that the typical horizontal travel speed of mobile occupants is in the order of 1.2 m/s – 1.4 m/s. However, a walking speed of 1.0 m/s is used in this analysis.

In the calculations that follow:

Travel Distance	The distance an occupant will have to travel.
Travel Speed	The assumed travel speed of occupants, which is assumed to be 1.0 m/s, as suggested for able bodied people by the SFPE Handbook.
Travel Time	The time taken for the last occupant to reach an available exit door.
Population	The number of persons within the relevant space (i.e. the enclosure within which the fire is assumed to occur).
Adjusted Exit Width	The total width of all the exit doors, adjusted to account for human tendencies to avoid walls etc. (70% of full width).
Exit Flow Rate	The number of persons that can fit through all of the exit doors (1.3 persons/m/s × adjusted door width as suggested by the SFPE Handbook).
Exit Congestion Time	The time taken for all persons to pass through the doors, not including time taken to get to the door.

<u>Summary of RSET</u>

The detail RSET calculations are depicted on the following pages for both the Base case and redundancy scenario.

The RSET calculated for the base case is: RSET = 325 s

The RSET calculated for the redundancy case is: $RSET_{(Red.)}$ = 415 s

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	Title:	Egress Calculation (PD7974 - Part 6)
		Date:
		Page: 1

Ref	Calculations			Comments
				Version 1.2
Ref 1	***System Levels as defined in PD7974 - Part 6***			
	Complexity of the building	B1		System Levels
	Alarm System Level	A3		M2-B1-A3
	Fire Safety Management Level	M2		
	Design Behavioural Scenario:	A		
	Occupant alertness:	Awake		
	Occupant familiarity:	Familiar		
	Occupant density:	Low		
	Enclosures/complexity:	One or many		
	Examples of Occupancy types:	Office or industrial		
	Design Population at Exit =	20	persons	
	Exit Route of Interest			
	Corridor, aisle, ramp, doorway	Yes		
	Stairs	No		
	Time from ignition to detection, Δt_{det} =	2.4	min	
	Time from detection to a general alarm, Δt_a =	0	min	**Long and unpredictable**
Ref 1	***Occupant Pre-Movement Time***			
	First occupants to move, $\Delta t_{pre(1st\ percentile)}$ =	1	min	
	Last occupants to move, $\Delta t_{pre(99th\ percentile)}$ =	2	min	
Ref 1	***Occupant Travelling Time***			
	Horizontal Travel (Corridor, aisle, ramp, doorway)			
	Unimpeded walking speed, $S_{max,horizontal}$ =	1.19	m/s	Not Used
	Unimpeded walking speed, $S_{max,horizontal}$ =	1	m/s	User-specified
	$F_{s,horizontal,max}$ (persons/s/m of effective width) =	1.3		
	Exit route element	Stairways, doors, archways		
	Clear width of path, $W_{horizontal}$ =	10	m	
	Boundary layer (each side)	0.15	m	
	Effective width of path, $W_{e,horizontal}$ =	9.7	m	
	Distance of travel to a protected route, $L_{horizontal}$ =	60	m	
	Horizontal walking time, $\Delta t_{trav(walking,horizontal)}$ =	1.00	min	User-specified
	Horizontal flow rate, $F_{c,max,horizontal}$ (persons/s) =	12.61		
	Occupant horizontal flow time, $\Delta t_{trav(flow),horizontal}$ =	0.03	min	

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Ref	Calculations			Comments
				Version 1.2
	<u>Vertical Travel (Stairs)</u>			
	Tread dimension	279	mm	
	Riser dimension	178	mm	
	Unimpeded walking speed, $S_{max,vertical}$ =	0.95	m/s	For abled-bodied
	Unimpeded walking speed, $S_{max,vertical}$ =		m/s	Not Used
	$F_{s,vertical,max}$ (persons/s/m of effective width) =	1.01		
	Clear width of path, $W_{vertical}$ =	5	m	
	Exit route element Stairways, doors, archways			
	Boundary layer (each side)	0.15	m	
	Effective width of path, $W_{e,vertical}$ =	4.7	m	
Ref 2	Height of vertical travel, H =	0	m	
	Conversion Factor (vertical to horizontal travel) =	1.85		
	Distance of travel to a protected route, $L_{vertical}$ =	0.0	m	
	Vertical walking time, $\Delta t_{trav(walking,vertical)}$ =	0.00	min	
	Vertical flow rate, $F_{c,max,vertical}$ (persons/s) =	4.75		
	Occupant vertical flow time, $\Delta t_{trav(flow),vertical}$ =	0.00	min	
Ref 1				

Evacuation Time

Greater of

$$\Delta t_{evac} = \Delta t_{pre(1^{st}\ percentile)} + \Delta t_{trav(walking)} + \Delta t_{trav(flow)}$$

or

$$\Delta t_{evac} = \Delta t_{pre(99^{th}\ percentile)} + \Delta t_{trav(walking)}$$

Walking time (unimpeded), $\Delta t_{trav(walking)}$		1.00	min
Occupant flow time through exits, $\Delta t_{trav(flow)}$ =		0.03	min
Evacution time, Δt_{evac}		3.00	min

Required Safe Egress Time (RSET)

RSET = $\Delta t_{det} + \Delta t_a + \Delta t_{pre} + \Delta t_{trav}$ =		**5.4**	min
		325	seconds

Available Safe Egress Time (ASET)

ASET	=	600	seconds
Margin	=	275	seconds

Ref	Calculations	Comments
		Version 1.2

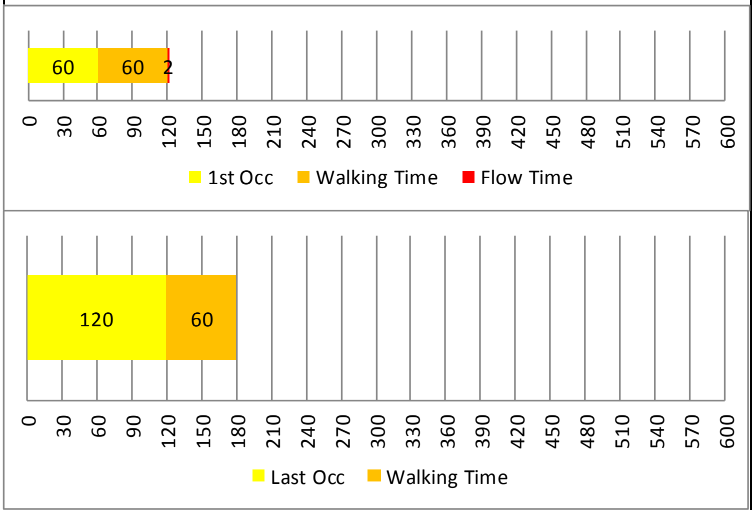

Figure 1: Evacuation Time

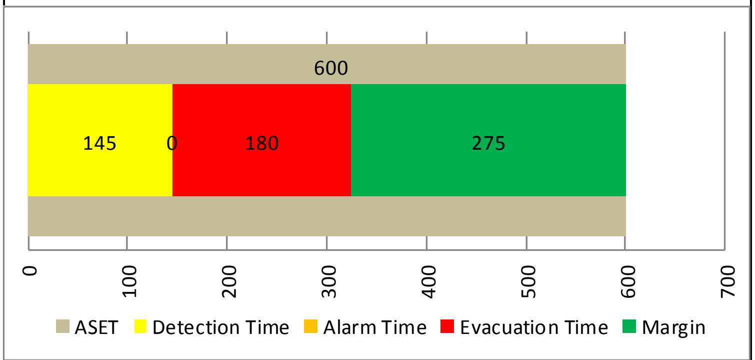

Figure 2: ASET vs RSET

References

1. BSI, *PD7974 The application of fire safety engineering principles to fire safety design building - Part 6: Human factors: Life safety strategies - Occupant evacuation behaviour and condition (Sub-system 6)* , BSI, 2004.

2. Gwynne, S. M. V., and Rosenbaum, E. R., *Employing the Hydraulic Model in Assessing Emergency Movement*, Section 3/ Chapter 13, SFPE Handbook of Fire Engineering (4th Edition), National Fire Protection Association, and Society of Fire Protection Engineers, 2008.

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Ref	Calculations			Comments
				Version 1.2
Ref 1	***System Levels as defined in PD7974 - Part 6***			
	Complexity of the building	B1		System Levels
	Alarm System Level	A3		M2-B1-A3
	Fire Safety Management Level	M2		
	Design Behavioural Scenario:	A		
	Occupant alertness:	Awake		
	Occupant familiarity:	Familiar		
	Occupant density:	Low		
	Enclosures/complexity:	One or many		
	Examples of Occupancy types:	Office or industrial		
	Design Population at Exit =	20	persons	
	Exit Route of Interest			
	Corridor, aisle, ramp, doorway	Yes		
	Stairs	No		
	Time from ignition to detection, Δt_{det} =	2.4	min	
	Time from detection to a general alarm, Δt_a =	0	min	**Long and unpredictable**
Ref 1	***Occupant Pre-Movement Time***			
	First occupants to move, $\Delta t_{pre(1st\ percentile)}$ =	1	min	
	Last occupants to move, $\Delta t_{pre(99th\ percentile)}$ =	2	min	
Ref 1	***Occupant Travelling Time***			
	Horizontal Travel (Corridor, aisle, ramp, doorway)			
	Unimpeded walking speed, $S_{max,horizontal}$ =	1.19	m/s	Not Used
	Unimpeded walking speed, $S_{max,horizontal}$ =	1	m/s	User-specified
	$F_{s,horizontal,max}$ (persons/s/m of effective width) =	1.3		
	Exit route element	Stairways, doors, archways		
	Clear width of path, $W_{horizontal}$ =	10	m	
	Boundary layer (each side)	0.15	m	
	Effective width of path, $W_{e,horizontal}$ =	9.7	m	
	Distance of travel to a protected route, $L_{horizontal}$ =	150	m	
	Horizontal walking time, $\Delta t_{trav(walking,horizontal)}$ =	2.50	min	User-specified
	Horizontal flow rate, $F_{c,max,horizontal}$ (persons/s) =	12.61		
	Occupant horizontal flow time, $\Delta t_{trav(flow),horizontal}$ =	0.03	min	

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Ref	Calculations			Comments
				Version 1.2
	Vertical Travel (Stairs)			
	Tread dimension	279	mm	
	Riser dimension	178	mm	
	Unimpeded walking speed, $S_{max,vertical}$ =	0.95	m/s	For abled-bodied
	Unimpeded walking speed, $S_{max,vertical}$ =		m/s	Not Used
	$F_{s,vertical,max}$ (persons/s/m of effective width) =	1.01		
	Clear width of path, $W_{vertical}$ =	5	m	
	Exit route element — Stairways, doors, archways			
	Boundary layer (each side)	0.15	m	
	Effective width of path, $W_{e,vertical}$ =	4.7	m	
Ref 2	Height of vertical travel, H =	0	m	
	Conversion Factor (vertical to horizontal travel) =	1.85		
	Distance of travel to a protected route, $L_{vertical}$ =	0.0	m	
	Vertical walking time, $\Delta t_{trav(walking,vertical)}$ =	0.00	min	
	Vertical flow rate, $F_{c,max,vertical}$ (persons/s) =	4.75		
	Occupant vertical flow time, $\Delta t_{trav(flow),vertical}$ =	0.00	min	
Ref 1	***Evacuation Time***			
	Greater of			
	$\Delta t_{evac} = \Delta t_{pre(1^{st}\ percentile)} + \Delta t_{trav(walking)} + \Delta t_{trav(flow)}$			
	or			
	$\Delta t_{evac} = \Delta t_{pre(99^{th}\ percentile)} + \Delta t_{trav(walking)}$			
	Walking time (unimpeded), $\Delta t_{trav(walking)}$	2.50	min	
	Occupant flow time through exits, $\Delta t_{trav(flow)}$ =	0.03	min	
	Evacution time, Δt_{evac}	4.50	min	
	Required Safe Egress Time (RSET)			
	RSET = $\Delta t_{det} + \Delta t_a + \Delta t_{pre} + \Delta t_{trav}$ =	**6.9**	min	
		415	seconds	
	Available Safe Egress Time (ASET)			
	ASET =	600	seconds	
	Margin =	185	seconds	

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Ref	Calculations	Comments
		Version 1.2

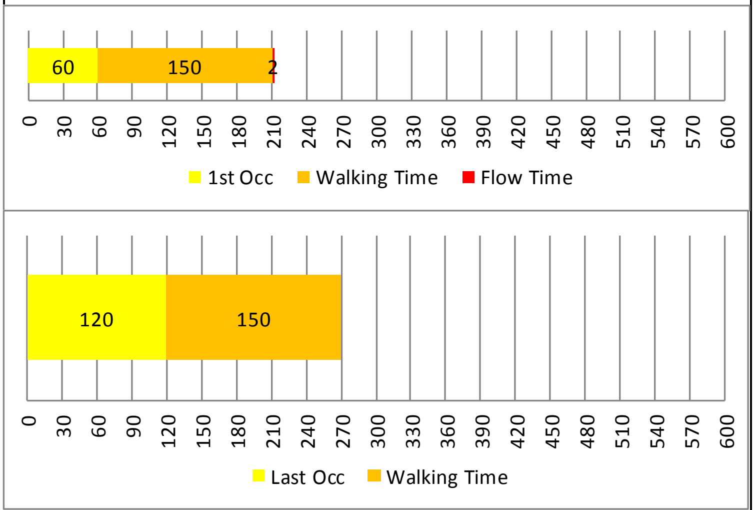


Figure 1: Evacuation Time

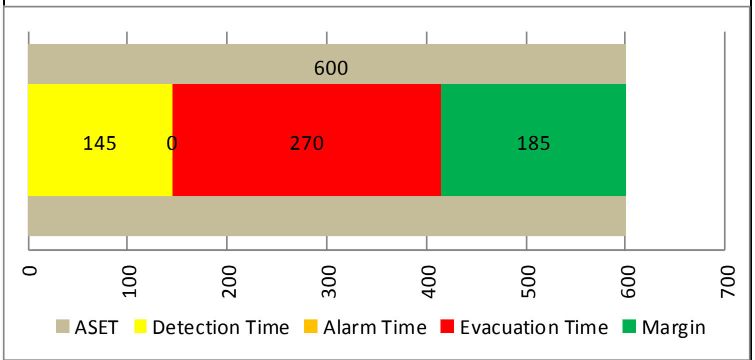


Figure 2: ASET vs RSET

References

1. BSI, *PD7974 The application of fire safety engineering principles to fire safety design building - Part 6: Human factors: Life safety strategies - Occupant evacuation behaviour and condition (Sub-system 6)* , BSI, 2004.

2. Gwynne, S. M. V., and Rosenbaum, E. R., *Employing the Hydraulic Model in Assessing Emergency Movement*, Section 3/ Chapter 13, SPFE Handbook of Fire Engineering (4^{th} Edition), National Fire Protection Association, and Society of Fire Protection Engineers, 2008.

A.6 CFD Model and assumptions

A three dimensional model was generated to represent the manufacturing area, as is shown in Figure 19. The following assumption were made:

1. Only one side of the building been modelled and the separation wall located between grid W15 and W16 is assumed a solid wall with no perforation. This creates a smaller compartment and more conservative smoke scenario.
2. The main entrance roller shutters were assumed to be open for all modelled scenarios.
3. No mechanical exhaust system were considered.
4. The fire foot print varies between 10 m^2 and 20 m^2 based on fire size.
5. Ceiling height varies from 12 to 14 m.
6. Make-up air for full combustion of the fire is assumed to be provided from the roller shutters.
7. No wall or ceiling leakages were allowed.

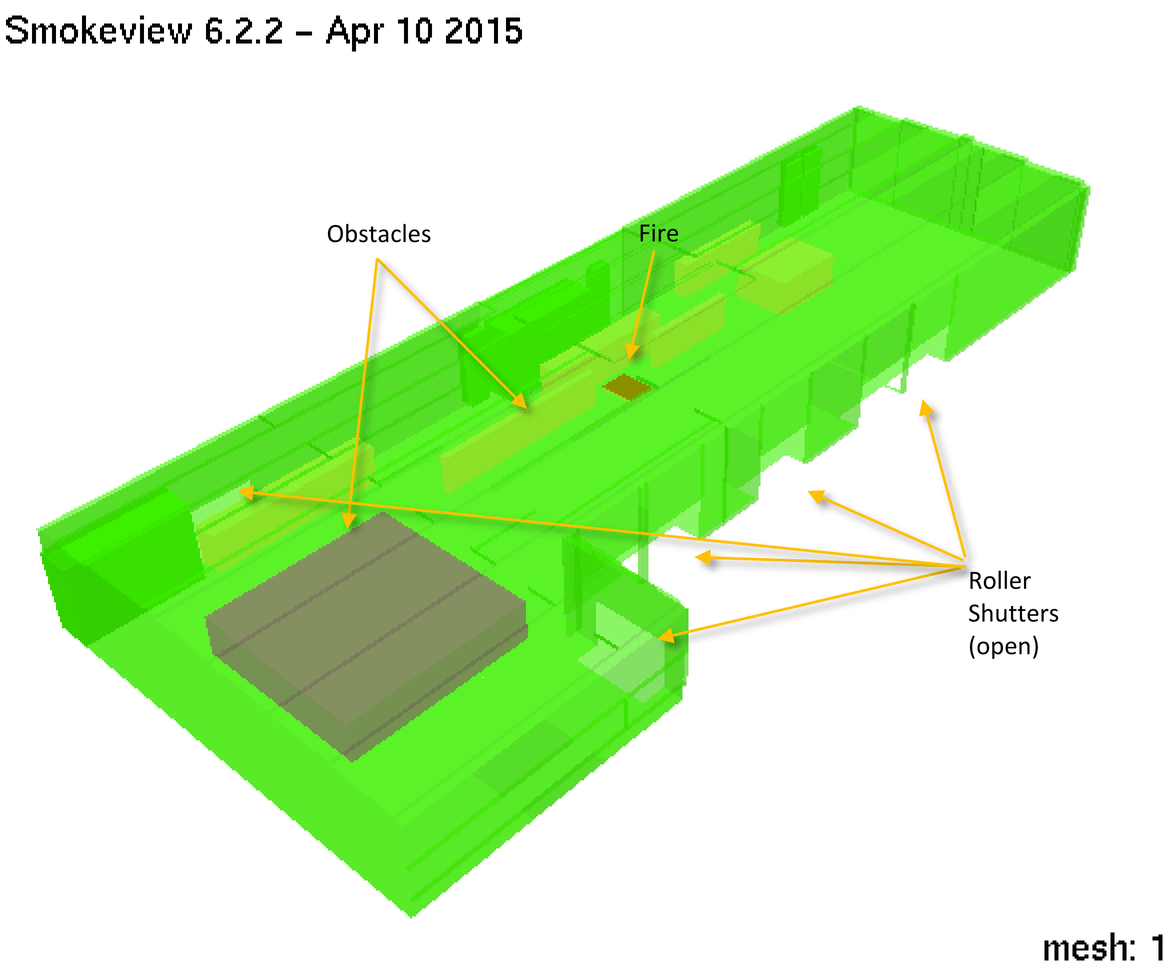
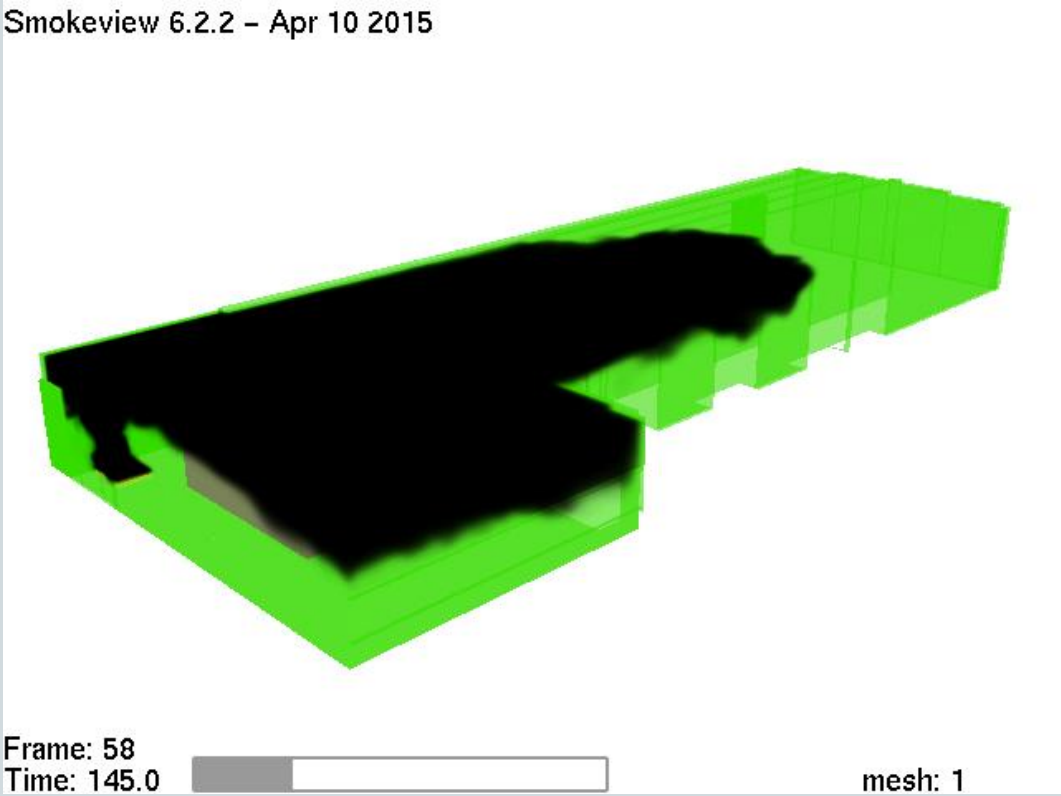
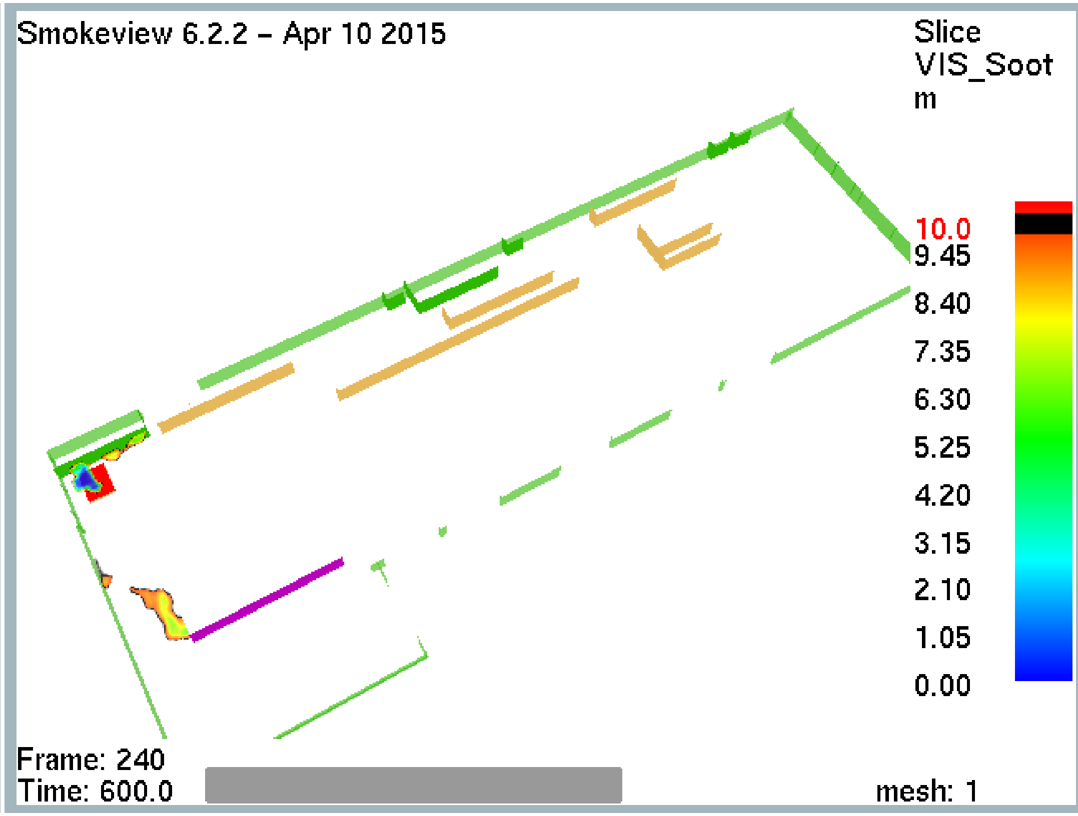


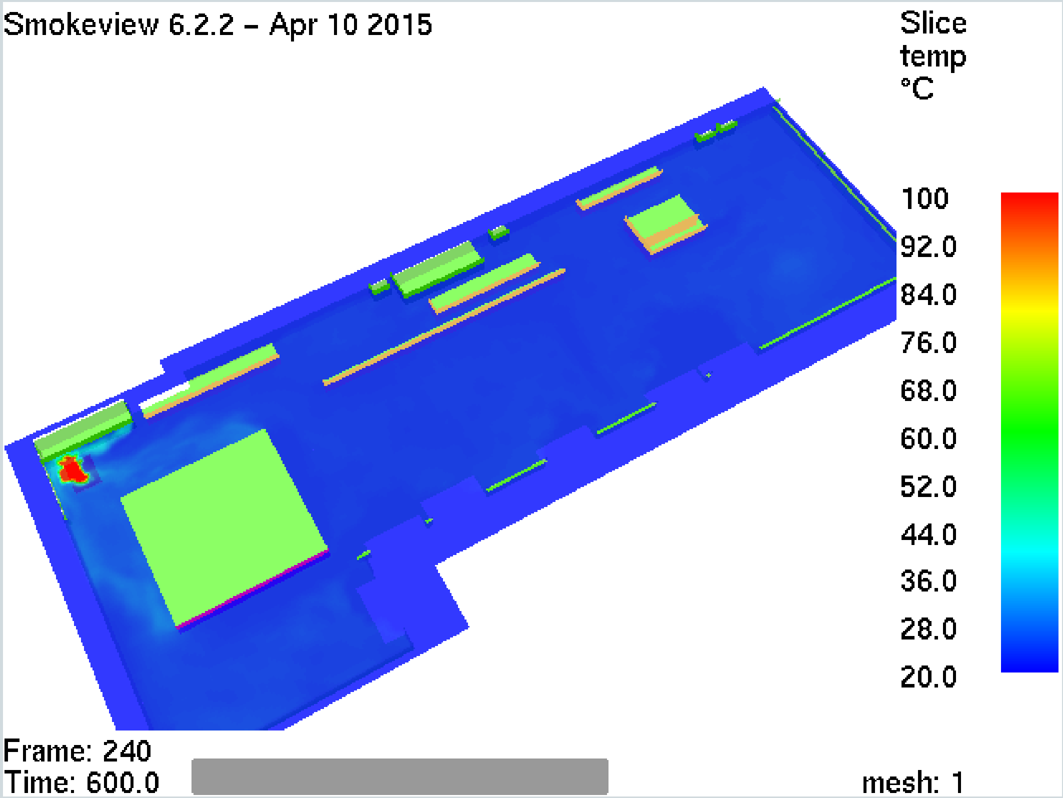
Figure 19: ISO view of the CFD model

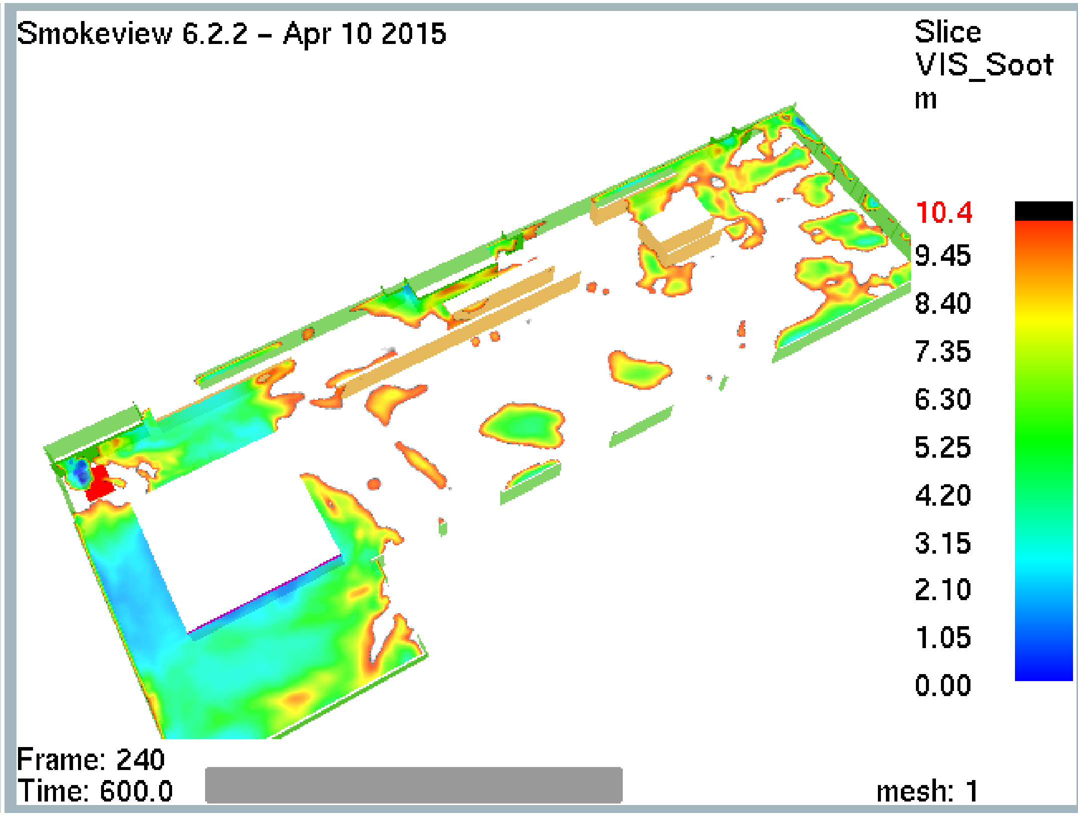
Appendix B FDS Results

B.1 Fire scenario Corner Fire (sensitivity case – south corner)

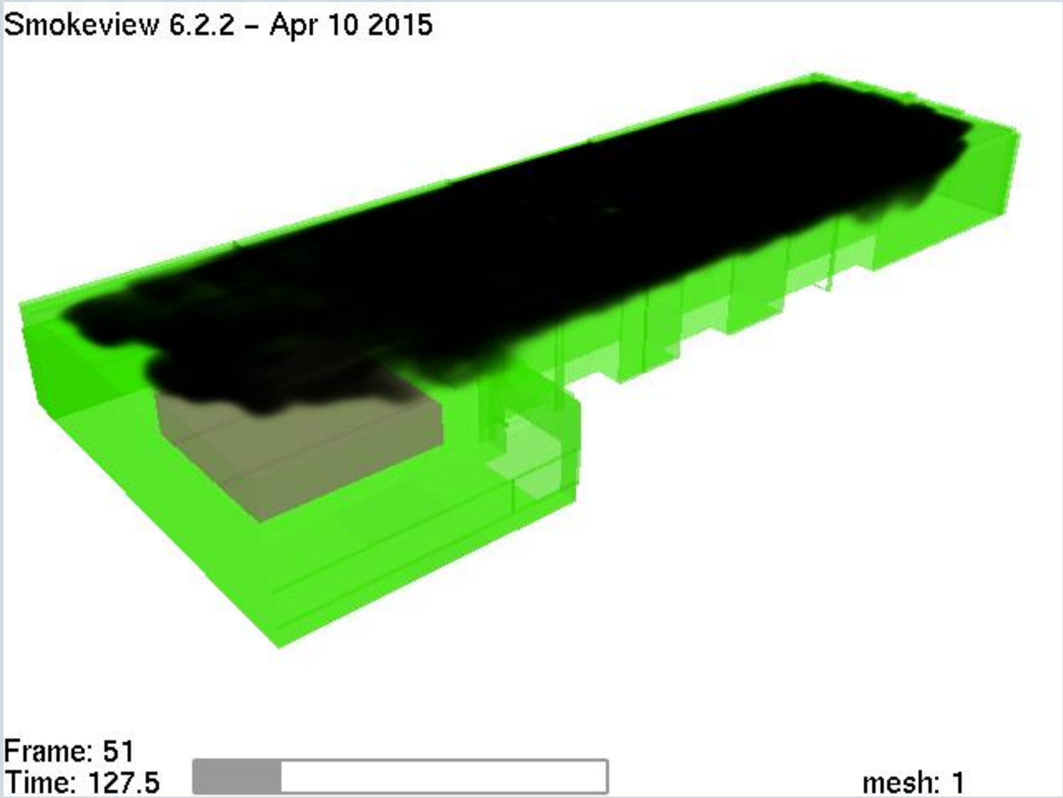
Stage	Time	Slice	Description
Observation & Occupant Alarm	145 s		At 145 s the ceiling smoke layer is filling more than half of the building. At this stage it is assumed most people within the building have noticed the fire given the open layout.

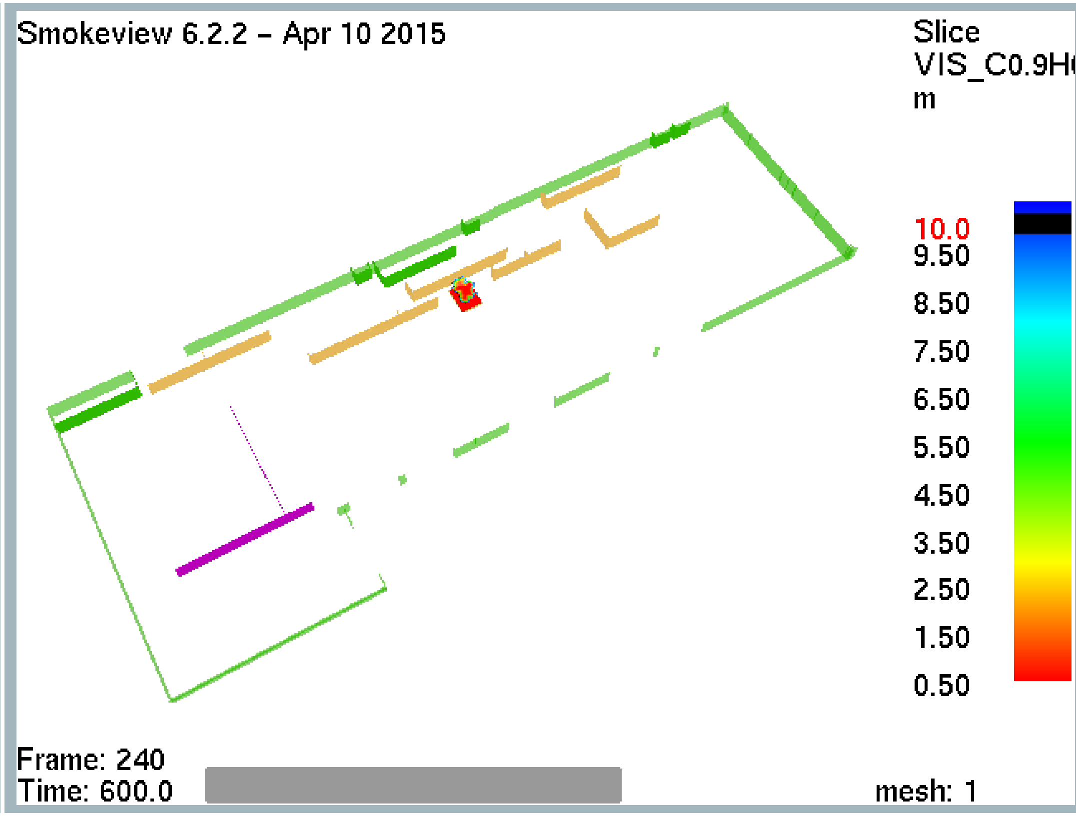
Stage	Time	Slice	Description
ASET	600 s		By the time when all occupants are expected to have evacuated, the visibility has not dropped below 10 m visibility.

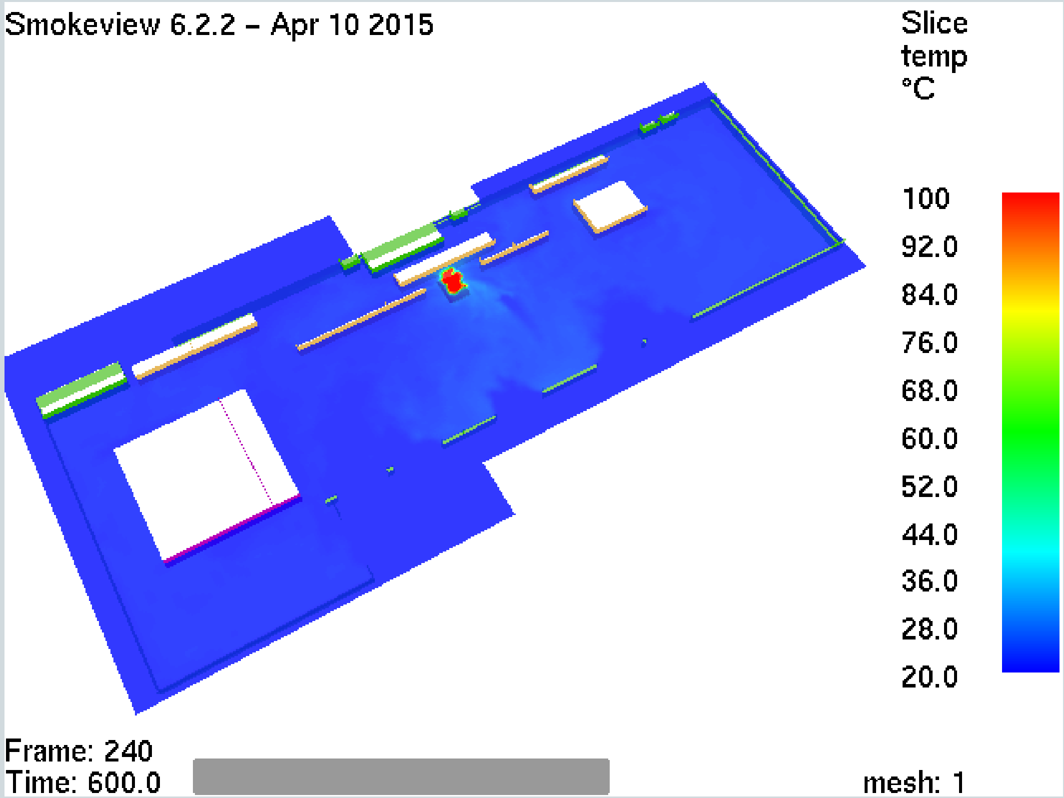
Stage	Time	Slice	Description
ASET	600		By the time when all occupants are expected to have evacuated, the temperature is still within acceptable range for both occupant and fire brigade tenability.

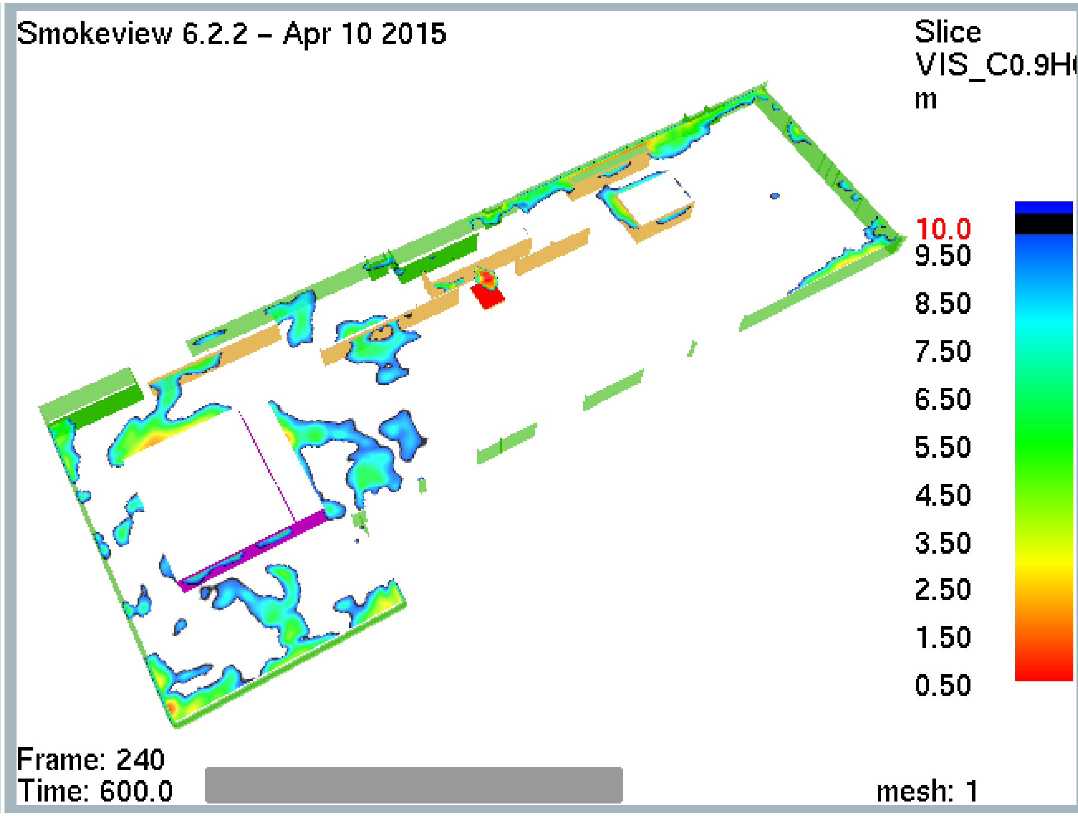
Stage	Time	Slice	Description
ASET – 4m Height	600s		By the time occupants have evacuated, exit sign visibility at the 4 m height has been maintained throughout most of the building, noting that there are no exits along the left (north) wall.

B.2 Fire scenario Centre Fire (sensitivity case – centre)

Stage	Time	Slice	Description
Observations	128		At 128 s the ceiling smoke layer is filling most of the shed. At this stage we assume all people within the building have notice the fire.

Stage	Time	Slice	Description
ASET	600 s		By the time when all occupants are expected to have evacuated, the visibility has not dropped below 10 m visibility.

Stage	Time	Slice	Description
ASET	600 s		By the time when all occupants are expected to have evacuated, the temperature is still within acceptable range for both occupant and fire brigade tenability.

Stage	Time	Slice	Description
ASET – 4m Height	600s		By the time occupants have evacuated, exit sign visibility at the 4 m height has been maintained throughout most of the building, indicating navigation should not have been impacted.

Appendix C FRNSW Feedback via FEBQ Process

C.1 FRNSW Feedback via FEBQ Process

The following were the FEBQ comments provided from FRNSW via FEBQ v02, dated 07/02/2017, and where they have been addressed in this Fire Engineering Report.

#	Section	FRNSW Comment in FEBQ v2	OFR Comment
1.	Performance Solution 1 – Perimeter Access	In principle support is provided subject to the analysis in the FER demonstrating compliance with the performance requirements of the BCA.	Noted.
2.		As detailed in the provided plans the hydrant booster assembly will be located adjacent to the entrance driveway and water will be supplied via the onsite water storage tanks located some distance towards the rear of the property. It is assumed that feed hydrant access will be via a 150mm suction connection. FRNSW provide the following recommendations: Where fixed suction is provided for a fire brigade pumping appliance to draught from a water source, the following design parameters shall be met: (a) The maximum friction loss shall be 20 kPa. (b) The maximum vertical lift shall be 3 m. (c) The maximum volume of permanently fixed on-site dry pipe (above the lowest suction level) shall be 0.05 m3.	Noted. These recommendations have been provided to the Fire Services Engineer and will be incorporated.
3.		Additionally it is recommended that an appropriate hardstand be provided to allow FRNSW appliances to connect to the 150mm suction connection. Consideration should be given to the suction connection hoses used by FRNSW which are semi rigid in lengths of 2.4m which allow for slight bending. Further information regarding these requirements can be found at FRNSW guidance sheet No 5 – Hardstand Areas for FRNSW Appliances	Noted. These recommendations have been provided to the Fire Services Engineer and will be incorporated.
4.		No detail has been provided regarding the sprinkler tank and the sprinkler booster locations. If onsite storage water tanks are proposed, FRNSW recommends the hardstand should enable FRNSW pumping appliances to connect to the tanks without blocking/encroaching onto the perimeter access road. FRNSW recommend that a sketch is provided in the FER detailing the area surrounding the sprinkler tank(s) (if applicable) and sprinkler booster. The sketch is to show the location of the fire brigade pumping appliances connected to the sprinkler tank(s) suction connections and demonstrate that a FRNSW aerial appliance can safely manoeuvre past the pumping appliances whilst being considerate to Guidelines for Emergency Vehicle Access – Policy No. 4.	Noted. These recommendations have been provided to the Fire Services Engineer and will be incorporated.
5.	Performance Solution 2 – Egress and Smoke Hazard Management	FRNSW recommends the visibility criteria be specified at 4m to quantitatively assess the visibility of the signs. The above criteria does not state the height at which visibility will be measured.	Noted. This has been included in the analysis in Section 5.2.
6.		In principle support is provided subject to the acceptance criteria being clarified and all analysis inputs and assumptions being detailed in the FER and agreed upon by all relevant stakeholders, and the analysis demonstrating compliance with the Performance Requirements of the BCA.	Noted.
7.	Performance Solution 3 – Sliding door	In principle support is provided subject to the analysis in the FER demonstrating compliance with the performance requirements of the BCA.	Noted.

Appendix D Special Hazard Considerations

D.1 Introduction

The Resource Co development at 35-37 Frank St, Wetherill Park has been nominated as a 'Special Hazard' by Fire & Rescue New South Wales.

A meeting with FRNSW was held on 07 June 2017. Multiple design requirements were identified and agreed to (see Section 4.4 and Appendix F). Another outcome of the meeting was that the smoke hazard management for the manufacturing building was to be assessed using Computational Fluid Dynamic (CFD) modelling. The simulations are compared against criteria provided by FRNSW as to the tenability of the interior of the building for fire brigade operations.

Consultant Advice Notices were provided to FRNSW to discuss and address these issues. Revision R03, submitted 6 September 2017, was approved by FRNSW. Revision R03 has been reproduced in its entirety into Appendix D and Appendix E. The fire safety requirements from this work have also been integrated to the Fire Safety Measures Table (Table 8).

D.2 Computational Fluid Dynamic Modelling

Fire and smoke modelling analysis will be undertaken using the Computational Fluid Dynamics (CFD) computer program Fire Dynamics Simulator (FDS), developed by the US National Institute of Standards and Technology (NIST) to simulate thermal and mass flow in a building.

FDS is a field model, based on the approach of the Large Eddy Simulation technique, where transport of mass, momentum and energy from fire induced flows are solved numerically with a large number of 3-dimensional cells representing the physical space. This approach is considered suitable to simulate the flow of heat and smoke through a large area. FDS computes the temperature, density, pressure, velocity and chemical composition within each numerical grid cell at each discrete time step. Smokeview is a companion program that produces images and animations of the results. Because the model was originally designed to analyse industrial-scale fires, it can be used reliably when the heat release rate (HRR) of the fire is specified and the transport of heat and exhaust products is the principal aim of the simulation.

D.2.1. Grid Size

The selected numerical grid is critical to the outcome of the modelling. [NIST 1019-5] noted that *"in general, you should build an FDS input file using a relatively coarse mesh, and then gradually refine the mesh until you do not see appreciable differences in your results."* The guide highlights that for simulations involving buoyant plumes, a measure of how well the flow field is resolved is given by the non-dimensional expression D^*/δ_x, where D^* is a characteristic fire diameter.

$$D^* = \left(\frac{Q}{\rho_\infty c_p T_\infty \sqrt{g}}\right)^{\frac{2}{5}}$$

Where:

Q = heat release rate (kW)
p_∞ = ambient density (kg/m3) = 1.2 kg/m^3
c_p = ambient specific heat (kJ/kg.K) = 1.02 kJ/kg.K
T_∞ = ambient temperature (K) = 293 K
g = acceleration due to gravity = 9.8 (m/s^2)
δx = the nominal size of a mesh cell.

[NIST 1019-5] recommend that the D^*/δ_x value lies between 4 and 16. Therefore, for differing fire sizes there is a measured approach is required to the correct adoption of cell size.

	Fire Size (kW)												
	Grid Size (δx)	600	800	1200	1600	1750	2000	2500	5000	10000	16000	20000	40000
D*	0.6	1.3	1.5	1.7	1.9	2.0	2.1	2.3	3.0	4.0	4.8	5.3	7.0
D*	0.5	1.6	1.8	2.1	2.3	2.4	2.5	2.8	3.6	4.8	5.8	6.4	8.4
D*	0.4	2.0	2.2	2.6	2.9	3.0	3.2	3.5	4.6	6.0	7.3	7.9	10.5
D*	0.3	2.6	2.9	3.4	3.9	4.0	4.2	4.6	6.1	8.0	9.7	10.6	14.0
D*	0.25	3.1	3.5	4.1	4.6	4.8	5.1	5.5	7.3	9.6	11.6	12.7	16.8
D*	0.2	3.9	4.4	5.2	5.8	6.0	6.3	6.9	9.1	12.0	14.5	15.9	21.0
D*	0.15	5.2	5.8	6.9	7.7	8.0	8.4	9.2	12.2	16.1	19.4	21.2	27.9

Figure 20: Table of Fire Size to D*

Using a grid size of 0.5 m x 0.5 m x 0. 5 m a single mesh, with fire sizes of approximately 8,000 - 16,000 kW, this would represent D^*/δ_x values of between 4 and 6, consistent with [NIST 1019-5].

The raw storage side of the building and the PEF storage side shall be modelled as separate compartments and models, for the purposes of these CFD simulations.

D.3 Building Geometry

The interior of the manufacturing facility is largely modelled as solid obstructions for simplicity, with the machinery area blocked out to a height of 3 m to reduce the available air space within the building. All measurements are rounded to 0.5 m increments to compensate for the grid size.

D.3.1. Ridge Vent Design

The building utilises a ridge vent, running its full length.

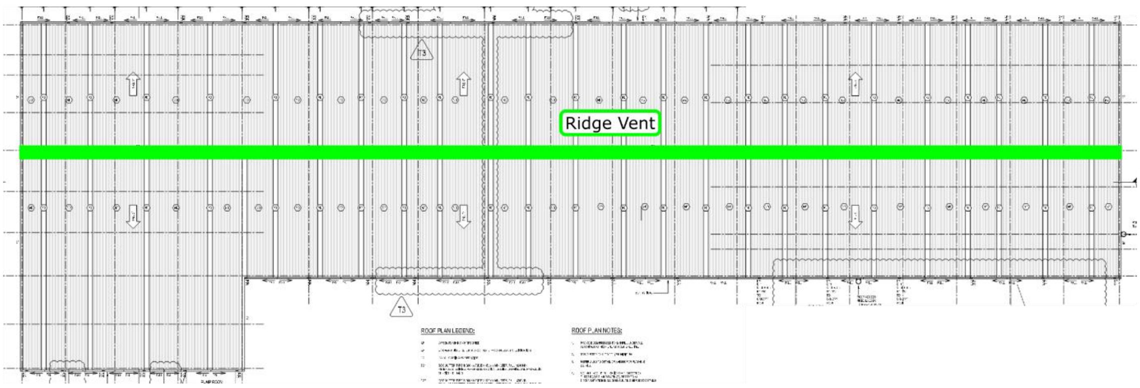


Figure 21: Ridge Vent placement

The ridge vent design provides an approximately 1200 mm wide throat at the top of the ridge, with two discharge points on either side of the ridge vent being approximately 600 mm wide each. An example of the ridge vent design is shown below.

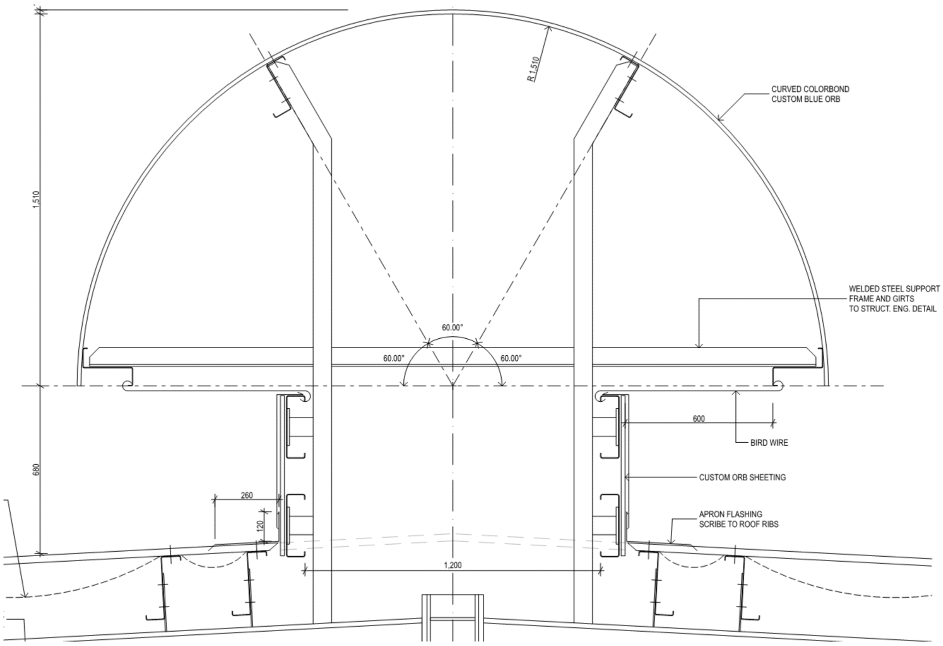


Figure 22: Section through Ridge Vent

Due to software restrictions, the model will conservatively assume that the throat is 1000 mm wide (in lieu of 1,200 mm), and that the discharge is 500 mm wide. Due to modelling restrictions an equivalent rectilinear design shall be modelled with dimensions smaller than the actual design which will add an additional layer of conservatism to the model.

D.3.2. Ventilation and Make Up air

The building is provided with a permanent 600 mm wide ventilation path around the perimeter of the building. This is depicted below. This opening shall be set at 500 mm for the model. The opening acts to provide the make-up air to the ridge vent.

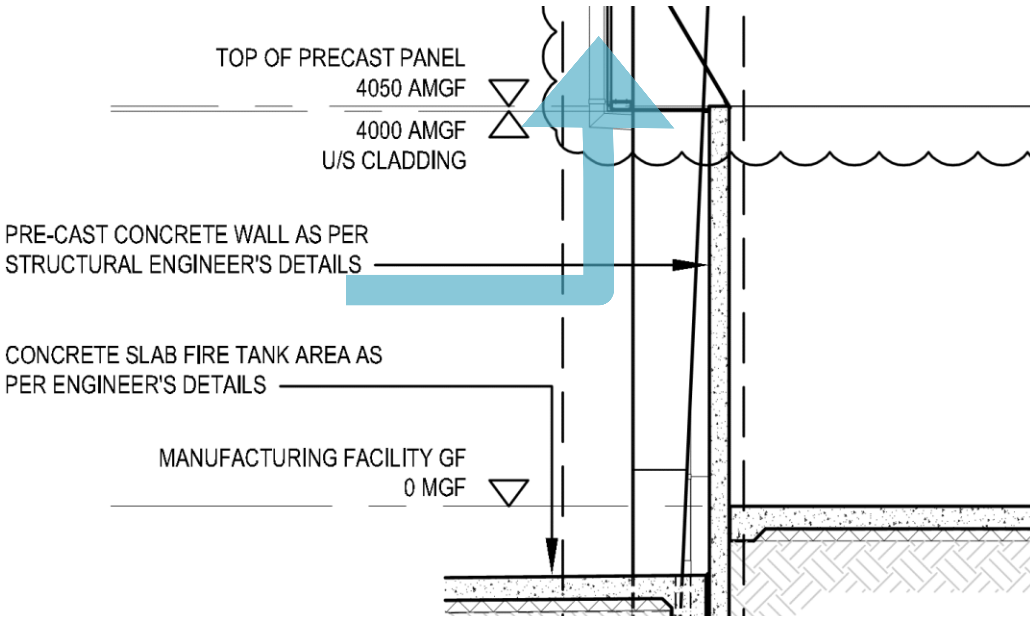


Figure 23: Section through Dado Wall

The only other openings in the exterior wall are the 2 m high occupant egress doors. These are to be modelled as open to ensure simulation of a fuel control fire (rather than oxygen controlled). No other openings are considered open for the purposes of the CFD model.

No building leakage is provided, therefore the only passage of air or smoke into or out of the building is via ridge vent, dado wall setback and doors.

A section through the CFD model is shown below which demonstrates the addition of the ridge vent and dado-wall openings.

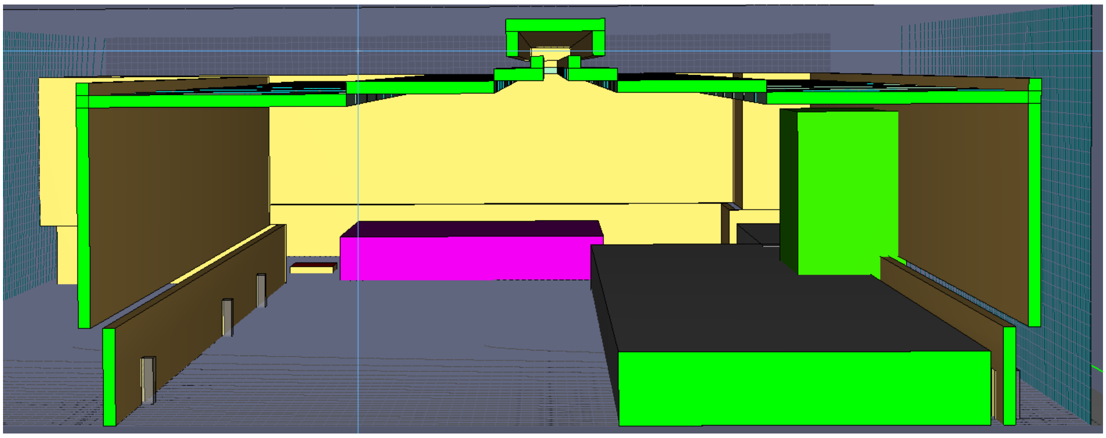


Figure 24: Depiction of CFD model (Section View) with Ridge Vent and Dado Wall Gap

The building has roller shutters for vehicular movement into both the Raw Feed and PEF areas. In the event additional make-up air is determined via CFD analysis to be required for the ridge vent, the models shall utilise these doors, which shall trip open upon sprinkler activation and BGA's.

D.4 Fire Scenarios

The following fire scenarios are proposed, as FRNSW guidance:

- Fire Size: Determined by first or second row sprinkler activation
- Fire Location: Centre and corner scenarios to be modelled for each area.

Each area therefore shall be represented by 4 models, for a total of 8 CFD models. Refer to comments below in relation to the total number of models required.

D.4.1. First Row Sprinkler Activation

The manufacturing building is provided with a sprinkler system throughout.

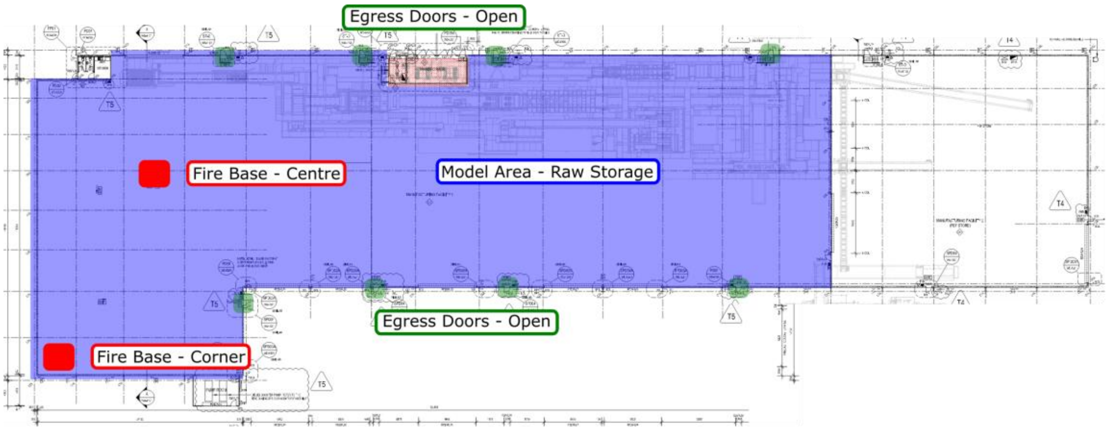
Whilst sprinkler activation is not proposed to be simulated activation of the inner row of sprinklers is proposed to determine the peak heat release rate.

D.4.2. Second Row Sprinkler Activation

A second scenario shall consider activation of automatic sprinklers being delayed until the second row.

D.4.3. Location of Fires

Fire shall be located in the centre and corner of the PEF and Raw Feed piles.



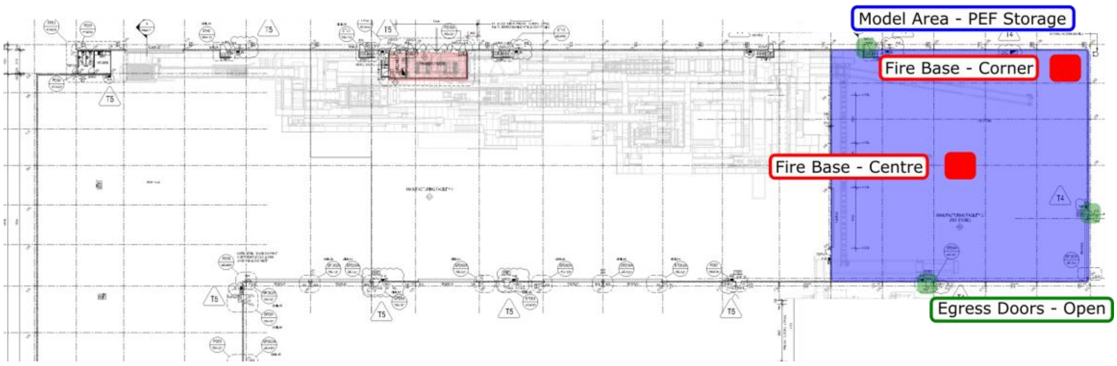


Figure 25: Proposed fire locations

D.4.4. Fire Parameters

1. Combustion reaction

The combustion process modelled is dependent on the fuel type as it governs oxygen consumption and heat release rate. FDS uses the smoke yield parameter for the generation of smoke within the CFD simulation (mass of smoke produced / mass of fuel burnt).

To account for the wide range of plastic materials forming part of the waste fuel load, and due to the difficulty in assigning multiple combustion reactions relating to the different materials, polyurethane will be used as the fuel source for the combustion model and will therefore be taken as representative of the material forming the fuel load for the CFD model. The soot yield and HRRPUA however will be determined further.

2. Soot Yield

Soot yield is determined via consideration for the breakdown of materials provided by the site operator, with regards to both the raw feed stockpiles and the PEF stockpile. The breakdown is as follows:

Raw feed stockpile

- Concrete, bricks, rocks – 10%
- Soil and other inert material – 15%
- Metals – 5%
- Timber – 35%
- Paper/cardboard/scrap plastics/textiles – 30%
- Green waste/food waste – 5%

PEF stockpile

- Timber – 50%
- Paper/cardboard/plastics/textiles – 40%
- Inert materials (e.g. dirt, glass) – 10%

Using these values, the soot yield of the aggregate materials in both cases can be estimated. [Purser] provides the base values for soot yield of various elements in a well ventilated fire:

Table 24: Determination of Soot Yield (RAW Feed)

RAW Feed	Portion	Soot Yield (g/g)	Proportional Soot Yield (g/g)	Note
Concrete/Bricks /Rocks	0.1	0	0	Inert, does not contribute
Soil/Inert	0.15	0	0	Inert, does not contribute
Metals	0.05	0	0	Inert, does not contribute
Timber	0.35	0.005	0.00175	Taken as 'Wood'
Paper/Cardboard/Plastics/Textiles	0.3	0.11	0.033	Taken as 'Polystyrene', being the highest value plastic noted.
Green waste /Food waste	0.05	0.11	0.0055	Unknown, so taken as 'Polystyrene', being the highest value plastic noted.
	Avg Soot Yield:	0.04		

Table 25: Determination of Soot Yield (PEF Product)

PEF Product	Portion	Soot Yield (g/g)	Proportional Soot Yield (g/g)	Note
Timber	0.5	0.005	0.0025	Taken as 'Wood'.
Paper/Cardboard/Plastics	0.4	0.11	0.044	Taken as 'Polystyrene', being the highest value plastic noted.
Inert	0.1	0	0	Inert, does not contribute
	Avg Soot Yield:	0.047		

It is noted that the estimated averaged soot yield would be approximately 0.04 g/g for the Raw Feed, and 0.047 g/g for the PEF material. To provide a level of conservatism to the model and to account for variability in the feed and final products, a soot yield of 0.1 g/g for both the Raw Feed and PEF material shall be used for the models.

3. Fire Growth Rate (Design Fire Growth Rate)

The fire growth rate determines the rate at which a fire grows. From [NFPA 92B], the following graph is representative of a general indication of various items.

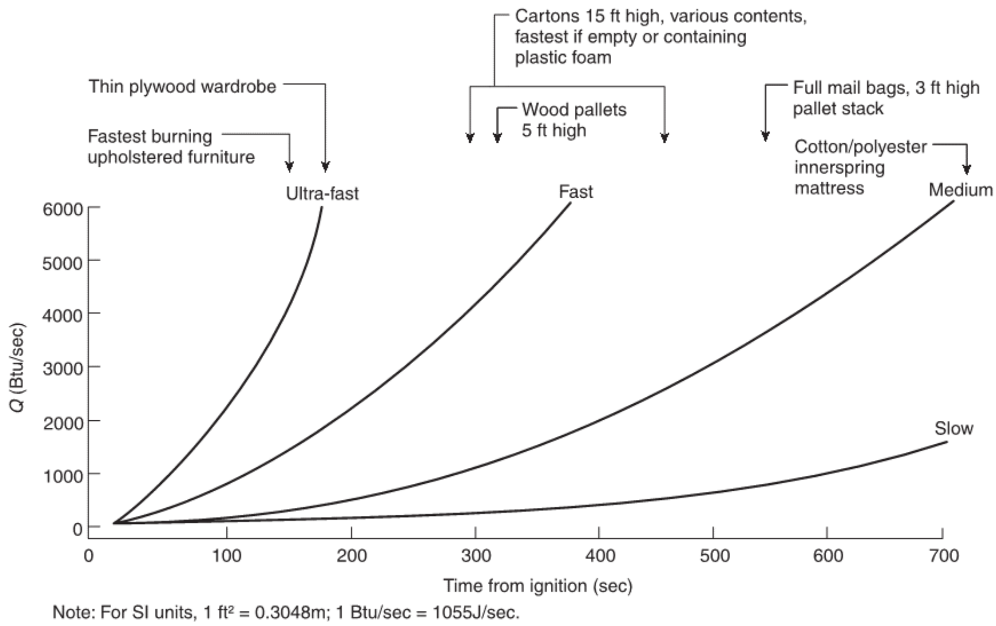


Figure 26: t^2 Fires to some elements [NFPA 92B]

The Raw Feed and PEF material both contain a mixture of materials, inclusive of inert material which not be expected to contribute to fire growth. As a measure of conservatism and in recognition that a homogenous material makeup is not present, an ultra-fast t^2 growth rate of fire is used for the CFD model.

Per Fire & Rescue New South Wales request, a medium t-squared fire has also been included in the design and has been modelled for all scenarios.

4. Fire Seat Height

The seat of the fire is to be located at ground level, in accordance with FRNSW request[2].

5. Heat Release Rate per Unit Area (HRRPUA)

[Fleishmann] details the effect that HRRPUA has on CFD modelling, as well as indicating HRRPUA ranges for various materials.

Peak HRRPUA values can range from ~ 245 kW/m2 for cardboard storage containers, up to potentially 3118 kW/m2 for PE barrels in cardboard cartons. The BRE fire safety engineering reference guide establishes a range of 250 kW/m2, with the upper limit being 2,000 kW/m2.

The effects that HRRPUA has on a CFD model also helps to determine an appropriate value, as visibility is affected by the HRRPUA values [Fleishmann]. This is reproduced below.

[2] We note that this requirement is conservative given the piled nature of the material. The lower the fire origin the more entrainment into the plume and as a result more smoke of lower temperature (and hence buoyancy) when compared to a fire located higher within the fuel load.

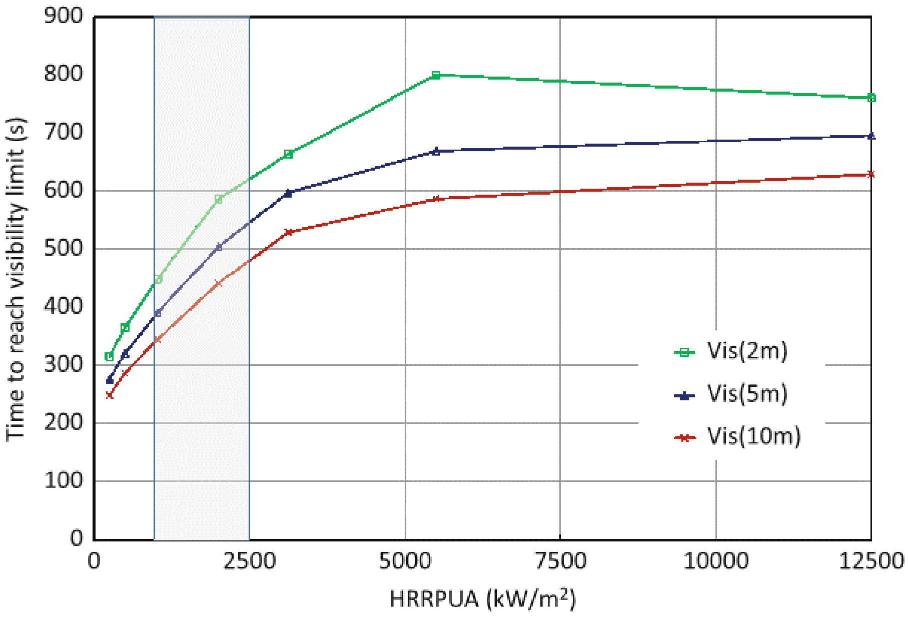


Figure 27: Time to reach visibility limit versus HRRPUA for 12 m high warehouse geometry [Fleishmann]

The research indicated that lower HRRPUA values cause visibility tenability to be lost *earlier*. Therefore, visibility is the key consideration a HRRPUA of 1,000 kW/m^2 is used as the model input. This value represents the lowest recommended value of HRRPUA for a mixed use site, and is expected to produce the most conservative CFD results with regards to visibility.

D.4.5. Design Fire Sizes

As the fire scenario for each area consists of a medium or ultra-fast t^2 growth rate fire growing until the first or second row of sprinklers activate, the maximum heat release rate for the models can be determined.

The determining factors are:

- Height above fire: 14 m, taken as maximum clearance height within the building.
- Distance from fire to first row sprinkler head: 2.45 m
- Distance from fire to second row sprinkler head: 5.48 m
- Sprinkler activation temperature: 93 °C
- Sprinkler RTI: 50 m$^{1/2}$s$^{1/2}$
- Ambient Temperature: 20 °C

Using Alpert's Correlation and [Schifiliti], the following estimated fire size at sprinkler activation for input into the CFD model is:

- Medium t^2 growth rate fire, first row sprinkler activation: 7 MW
- Medium t^2 growth rate fire, second row sprinkler activation: 15 MW
- Ultra-Fast t^2 growth rate fire, first row sprinkler activation: 8 MW
- Ultra-Fast t^2 growth rate fire, second row sprinkler activation: 16.9 MW

D.4.6. Summary of Fire Scenarios

A summary of the modelled fire scenarios are provided below. There are a total of 16 modelled fire scenarios performed.

Table 26: Modelled Scenarios

Scenario	Fire Growth Rate	Storage Area	Sprinkler Row Activation	Fire Location	Fire Size (MW)	HRRPUA (kW/m2)
1.	Medium	RAW	First	Centre	7	1,000
2.	Medium	RAW	First	Corner	7	1,000
3.	Medium	RAW	Second	Centre	15	1,000
4.	Medium	RAW	Second	Corner	15	1,000
5.	Medium	PEF	First	Centre	7	1,000
6.	Medium	PEF	First	Corner	7	1,000
7.	Medium	PEF	Second	Centre	15	1,000
8.	Medium	PEF	Second	Corner	15	1,000
9.	Ultra-Fast	RAW	First	Centre	8	1,000
10.	Ultra-Fast	RAW	First	Corner	8	1,000
11.	Ultra-Fast	RAW	Second	Centre	16.9	1,056
12.	Ultra-Fast	RAW	Second	Corner	16.9	1,056
13.	Ultra-Fast	PEF	First	Centre	8	1,000
14.	Ultra-Fast	PEF	First	Corner	8	1,000
15.	Ultra-Fast	PEF	Second	Centre	16.9	1,056
16.	Ultra-Fast	PEF	Second	Corner	16.9	1,056

D.5 Demonstration of Results

The results of the CFD analysis shall be demonstrated via Cartesian plane slice files in Smokeview, in accordance with FRNSW guidance:

- Visibility at a 4 m height, 1200 s after fire ignition.
- Visibility at a 2 m height, 415 s after fire ignition (Occupant RSET).
- Visibility at a 2 m height, 1800 s after fire ignition.

The visibility factor for all models shall be set to 3, for a non-light emitting source.

In order to provided clarity to the results, the slices will show areas only that fall below 10 m in visibility – all areas with greater tenability shall be shown as 'clear'. It is noted that this does not mean the area is free of smoke, only that the smoke density has not increased to the point of reducing visibility to less than 10 m. i.e. visibility through these areas may be obscured, but still greater than 10 m.

There are multiple aspects of acceptance criteria established, as the various heights dictate differing requirements.

D.5.1. Acceptance Criteria for 4 m Height Visibility

The purpose of visibility at 4 m height is to assist fire fighters in locating the seat of the fire to facilitate fire brigade intervention. 4 m is based on the maximum storage height within the building. In this case, the acceptance criteria is therefore that visibility is such that it can be expected that the fire brigade are able to determine an elevated fire base location.

This acceptance criteria shall be demonstrated via one of two methods, method a) being a general method, and b) being a more specific method:

a) The acceptance criteria is considered to be met if no greater than 25% of the space, at 4 m above ground, experiences visibility < 10 m, by 1200 s. No further analysis in this case will be required.

b) In the event that a) is not demonstrated, the analysis must detail that an elevated fire base is provided with line of sight visibility for attending brigade officers from a height approximately 2 m above ground for a distance of at least 10 m.

Obscuration of up to 25 % of the area is considered acceptable in this case as elevated height visibility is *not* anticipated to impact on the egress of occupants or general movement of the fire brigade. The most pertinent area for this criterion is close to the fire base, as heavy obscuration of an elevated fire base may delay fire brigade intervention. Obscuration around the perimeter of the building, or above exits or egress pathways, would not be considered relevant acceptance criteria as obscuration at 4 m heights is not anticipated to impact on the use of exits or egress pathways.

D.5.2. Acceptance Criteria for 2 m Height Visibility

The purpose of visibility at 2 m height is to enable occupant egress, and fire brigade intervention activities (or evacuation if required). In this case, tenability shall be considered to be met if no greater than 10% of the space, at 2 m above ground, experiences visibility < 10 m.

Two times shall be considered:

- 415 seconds, which is the estimated time calculated in the Fire Engineering Report to be the Required Safe Egress Time (RSET) of occupants within the building, which accounts for travelling to an exit, finding it blocked, and travelling to an alternative exit (back through the point of choice).
- 1800 seconds, which was prescribed via FRNSW guidance as the required time for tenability demonstration at 2 m for fire brigade intervention activities.

In the event that overall tenability is lost, the results shall be subject to further analysis.

Both times shall also give consideration for exit pathways and egress routes, in that the loss of a single exit due to smoke obscuration at a 2 m height, at either time, will require additional analysis and demonstration of adequacy.

The further analysis shall examine where the visibility criteria has been lost, and whether it can be expected to inhibit occupant egress or brigade intervention. If the analysis is able to demonstrate that limited loss of visibility of an egress pathway would not be expected to unduly affect occupants or the fire brigade, the acceptance criteria will be met.

D.6 Trial Design

The fire safety measures proposed are:

- A ridge vent, running the length of the building at the highest point, shall be provided to meet the following requirements:
    - Minimum throat open diameter of 1,200 mm
    - Protected from wind via shielding for the length of the ridge vent, such that any inlet/discharge is not exposed to the horizontal movement of air or wind external to the building.
    - The ridge vent design shall meet or exceed the design exhaust capacity noted in Section D.6, Table 27.
- Make-up air is to be provided by the dado-wall setback from the steel-clad wall by at least 500 mm, around the perimeter of the building.
- The roller shutter for the PEF storage area shall open upon sprinkler activation to provide additional make-up air and venting capabilities to the PEF area. Cabling to the roller shutters shall be in accordance with AS 1668.1.

The ridge vent for the building was modelled based on a provided architectural design. The design provided is estimated to provide these exhaust capacity, and the final building design shall meet or exceed this capacity:

Table 27: Estimated exhaust capacity for Ridge Vent

DeltaT	Stack Height (m)	Exhaust capacity at nil wind (m^3/m^2)	RAW exhaust capacity (m^3/s)	PEF exhaust capacity (m^3/s)	Total exhaust capacity (m^3/s)
5	6	0.78	101.4	31.2	132.6
5	9	0.96	124.8	38.4	163.2
5	12	1.11	144.3	44.4	188.7
5	15	1.24	161.2	49.6	210.8
10	6	1.11	144.3	44.4	188.7
10	9	1.35	175.5	54	229.5
10	12	1.56	202.8	62.4	265.2
10	15	1.75	227.5	70	297.5
15	6	1.35	175.5	54	229.5
15	9	1.66	215.8	66.4	282.2
15	12	1.92	249.6	76.8	326.4
15	15	2.14	278.2	85.6	363.8

D.7 Results

The results of the CFD models have been tabulated on the following pages. Each scenario that has been identified is provided with three slice screen shots, one at 1200 s (4 m height), one at 415 s (2 m height) and one at 1800 s (2 m height), depicting the areas where smoke had descended to obscure visibility to < 10 m. Additional slice screen shots are provided through sections of the model. To assist in providing clarity to which areas of a modelled fire scenario lose tenability, only the areas with less than 10 m visibility are depicted in the results.

The following summary of results are provided, with Table 28 providing details in addition to the Appendix Tables for each modelled scenario:

- For brigade intervention and identification of an elevated fire base location, most models achieve the acceptance criteria part a). Scenario 7 and 8 are subject to further analysis. As well, per FRNSW guidance, Scenario 11, 12, 14 and 15 will also be discussed further.
- For occupant egress, the visibility at 2 m after 415 s has been demonstrated to be maintained in all 16 scenarios. It is therefore considered that occupant egress meets the acceptance criteria.
- For brigade movement and visibility at 2 m, visibility after 1800 s has been demonstrated to be maintained in all 16 models. However, as a matter of robustness, limited occurrences of reduced visibility at one exit in Scenarios 7 and 11 are noted and will be discussed further.

Table 28: Scenario Results – See Appendix for Slices

Scenario	Fire Growth Rate	Storage Area	Sprinkler Row Activation	Fire Location	Visibility at 4m Height 1200 s	Visibility at 2m Height 415 s	Visibility at 2m Height 1800 s
1.	Medium	RAW	First	Centre	Met	Met	Met
2.	Medium	RAW	First	Corner	Met	Met	Met
3.	Medium	RAW	Second	Centre	Met	Met	Met
4.	Medium	RAW	Second	Corner	Met	Met	Met
5.	Medium	PEF	First	Centre	Met	Met	Met
6.	Medium	PEF	First	Corner	Met	Met	Met
7.	Medium	PEF	Second	Centre	Assess Further	Met	Assess Further
8.	Medium	PEF	Second	Corner	Assess Further	Met	Met
9.	Ultra-Fast	RAW	First	Centre	Met	Met	Met
10.	Ultra-Fast	RAW	First	Corner	Met	Met	Met
11.	Ultra-Fast	RAW	Second	Centre	Assess Further	Met	Assess Further
12.	Ultra-Fast	RAW	Second	Corner	Assess Further	Met	Met

Scenario	Fire Growth Rate	Storage Area	Sprinkler Row Activation	Fire Location	Visibility at 4m Height 1200 s	Visibility at 2m Height 415 s	Visibility at 2m Height 1800 s
13.	Ultra-Fast	PEF	First	Centre	Met	Met	Met
14.	Ultra-Fast	PEF	First	Corner	Assess Further	Met	Met
15.	Ultra-Fast	PEF	Second	Centre	Assess Further	Met	Met
16.	Ultra-Fast	PEF	Second	Corner	Met	Met	Met

D.8 Secondary Assessment – 4 m Height Models

Scenarios 7, 8, 11, 12, 14 and 15 exhibit results which indicate that the smoke spill is likely to, or does exceed the "25%" initial acceptance criteria. This section discusses the results in more detail in order to demonstrate the suitability of the design.

In each scenario, the smoke layer has started to descend below 4 m in height with sufficient density to obscure portions of the building area. However, in each scenario, this level of reduced visibility is not centred around the fire base itself, but mostly remote to the fire base.

For Scenario 7 (see Figure 28) and Scenario 14 and 15 which show similar results, the reduced visibility occurs at the perimeter of the enclosures as the smoke layer meets the bounding walls. The smoke layer at the perimeter of the enclosure is not "deep" and 10 m visibility to the elevated fire base would still be achieved as is the requirement of FRNSW. This is also demonstrated in Figure 29, which shows that the smoke layer has been maintained at elevated heights closer to the fire, which is therefore anticipated to permit line of sight with the fire base by the brigade at ground level.

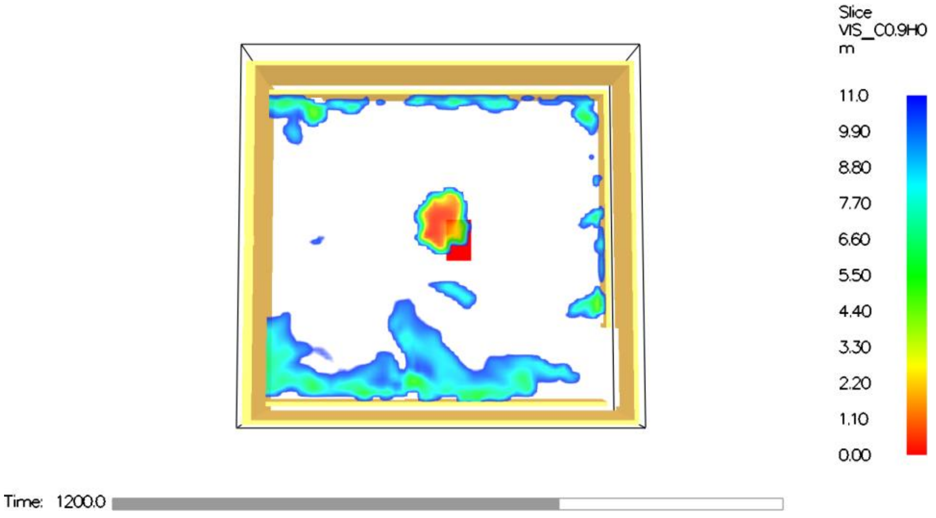


Figure 28: Scenario 7, 4 m Height Visibility at 1200 s (Scenario 14 and 15 similar results)

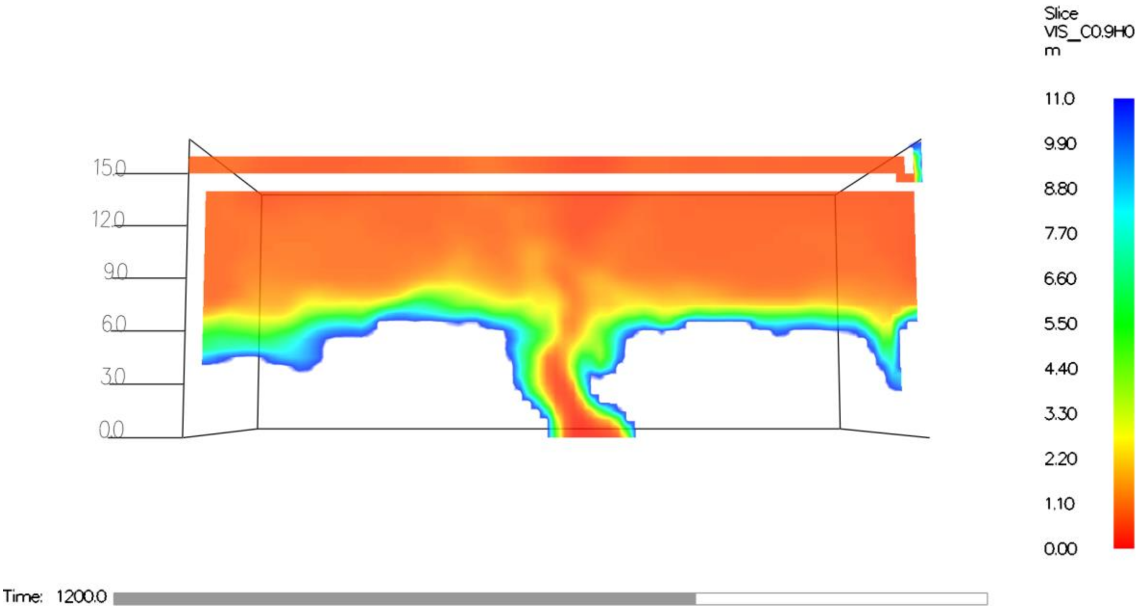


Figure 29: Scenario 7, Vertical Slice of Visibility at 1200 s (Scenario 14 and 15 similar)

For Scenario 8, the following slices in Figure 30 and Figure 31 is provided from the modelling at 4 m in height.

It is noted that in this case, some elevated obscuration near the fire base may occur. This is likely due to the effect of being a corner fire, and the entrainment of smoke that occurs due to the wall nearby. However, the fire seat is still visible from the opposing side of the enclosure (~2.5 sides). Further to this, visibility at 2 m at this time is maintained to the egress/intervention areas, as indicated in Figure 32, further facilitating fire brigade intervention activities at the time. It is therefore anticipated that the brigade would have visible line of sight of at least 10 m to the elevated fire base.

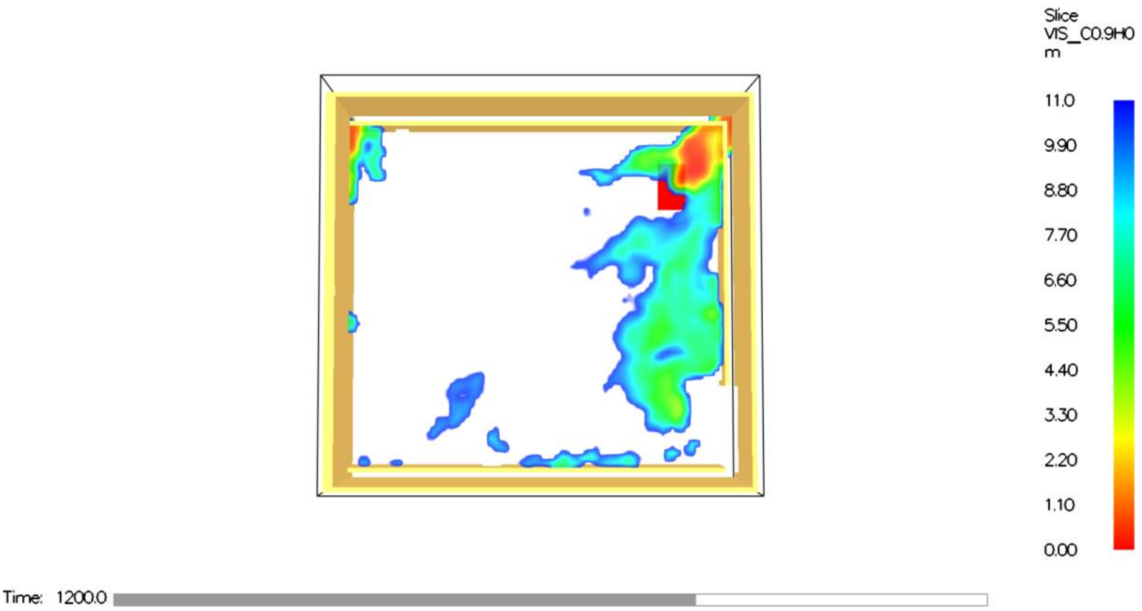


Figure 30: Scenario 8, 4 m Height Visibility at 1200 s

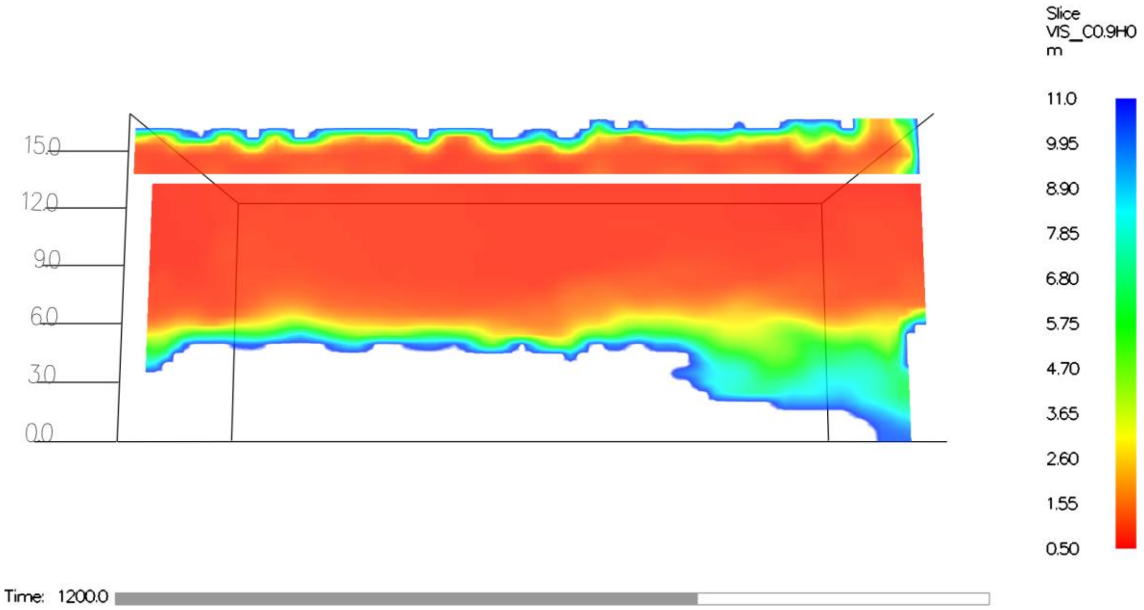


Figure 31: Scenario 8, Vertical Slice of Visibility at 1200 s

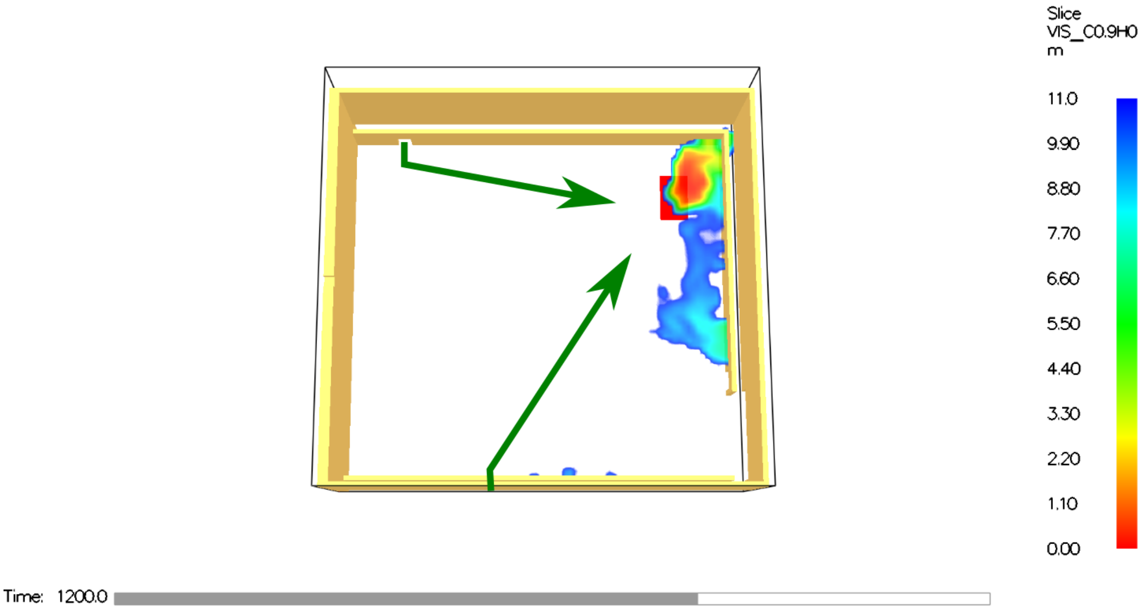


Figure 32: Scenario 8, 2 m Height Visibility at 1200 s

Scenario 11 (refer to Figure 33) and Scenario 12 display similar results. In both cases, smoke obscuration at the far corner of the building has intensified such that visibility has dropped below 10 m at 4 m elevated height. However, visibility at and around the fire base is at least 10 m, consistent with the acceptance criteria for allowing line of sight visibility to the elevated fire base. The primary areas of obscuration are occurring distant to the fire base itself, thus not expected to impact on identifying the fire base location.

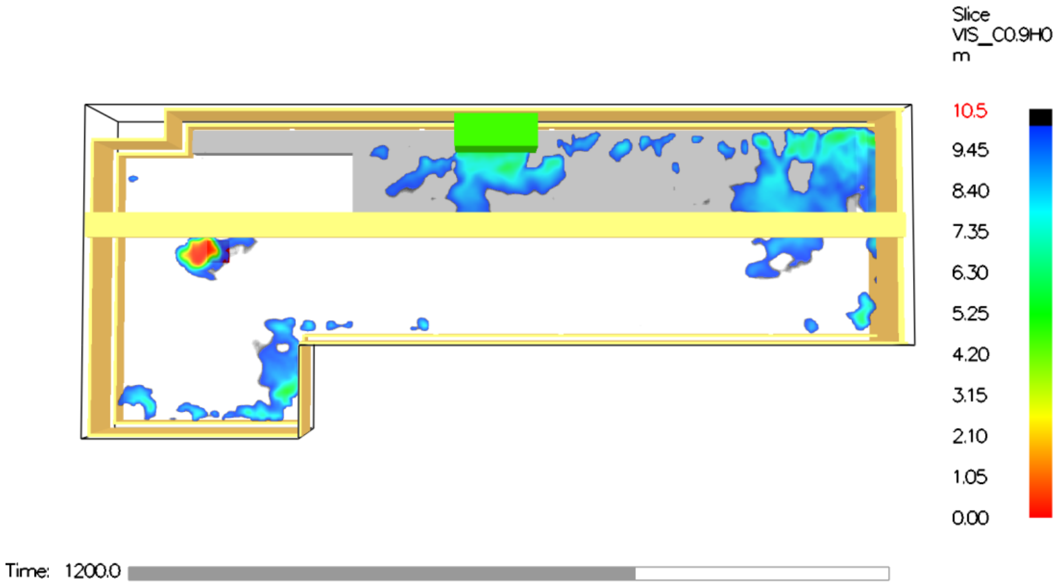


Figure 33: Scenario 11, 4 m Height Visibility at 1200 s (Scenario 12 similar)

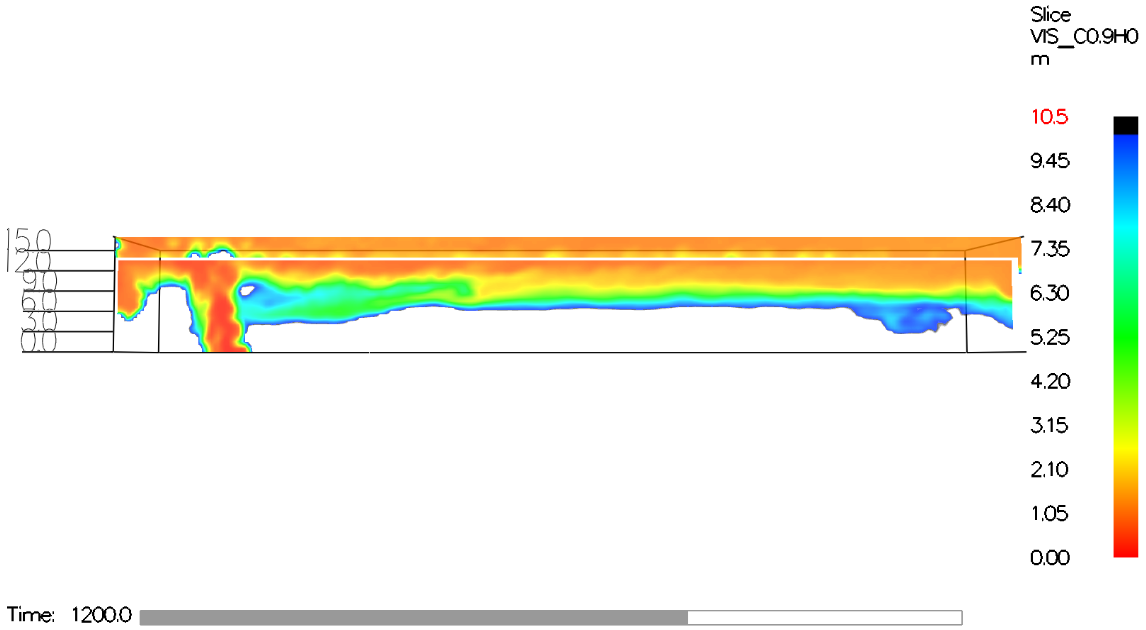


Figure 34: Scenario 11, Vertical Slice of Visibility at 1200 s (Scenario 12 similar)

D.9 Further Assessment – 2 m Height Models

Out of the 16 Scenarios, only 2 are noted to have a descent of smoke that is substantial enough to warrant further assessment, and only at 1800 s. In both Scenario 7 and 11, it is not that the overall level of visibility has been decreased such that tenability is called, it is that visibility of a single exit has become partially obscured. These are depicted below, with the obscured exit in red. Alternative available exits are in green.

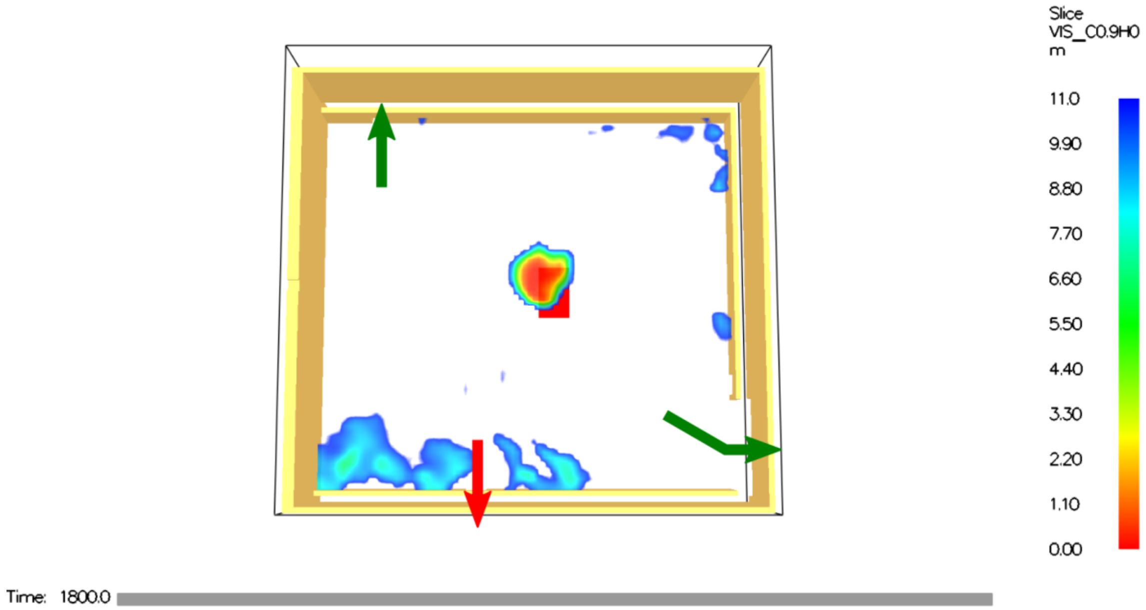


Figure 35: Scenario 7, 2 m Height Visibility at 1800 s

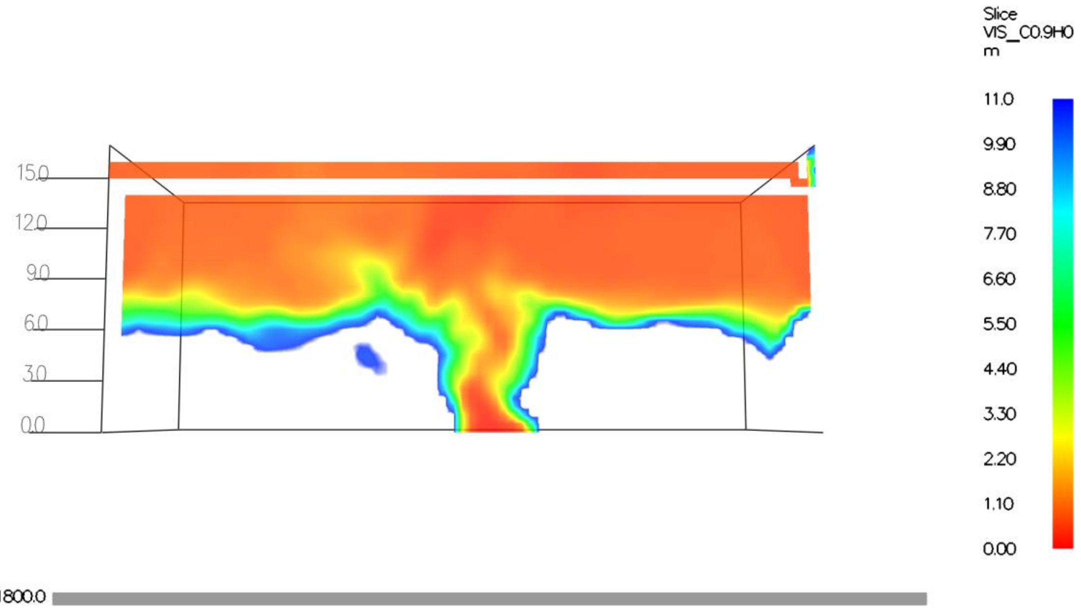


Figure 36: Scenario 7, Vertical Slice of Visibility at 1800 s

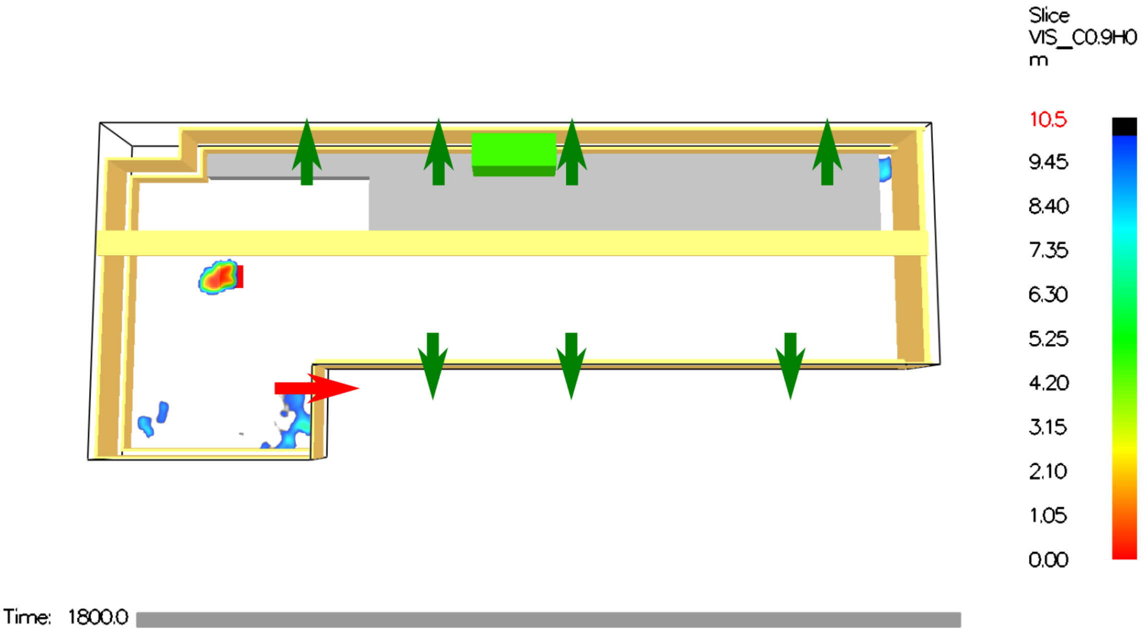


Figure 37: Scenario 11, 2 m Height Visibility at 1800 s

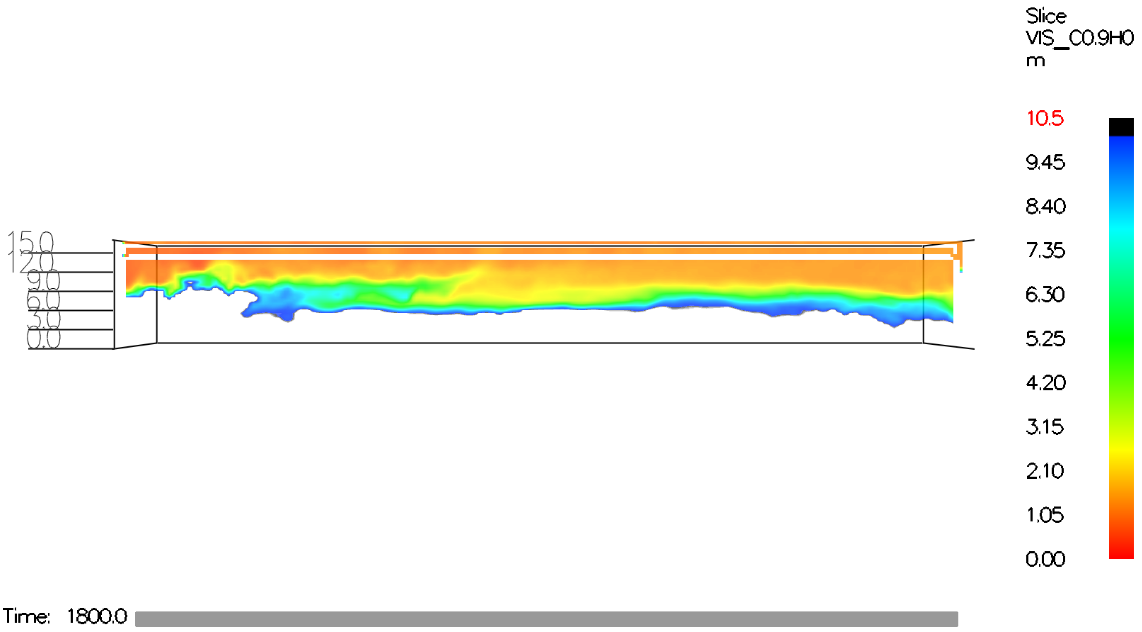


Figure 38: Scenario 11, Vertical Slice of Visibility at 1800 s

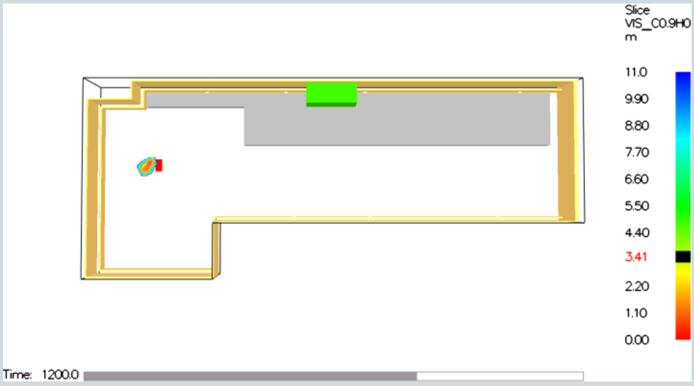
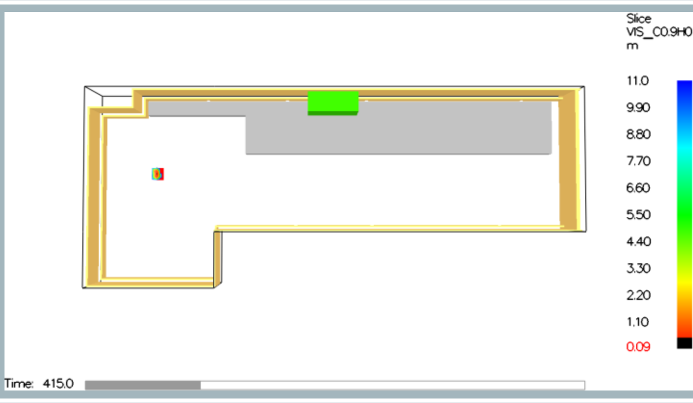
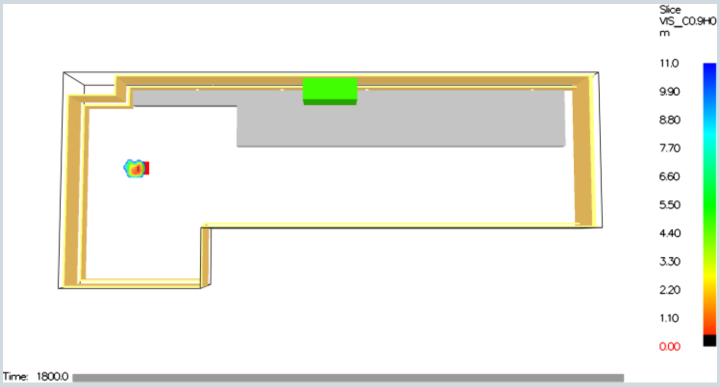
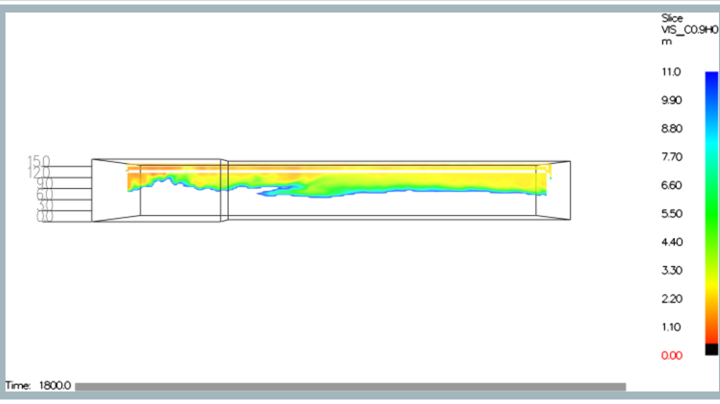
In both cases (and consistent with all other scenarios), all other egress pathways and exits are maintained. The obscuration of an exit in both cases is limited to the point adjacent to the exit itself, and therefore the exit signage, may still be visible (light illuminating signs have conservatively been ignored). Further, secondary nearby exits are still available and have maintained adequate visibility. The obscuration of a single exit is therefore not anticipated to unduly affect fire brigade intervention activities, and therefore the acceptance criteria is considered to be met.

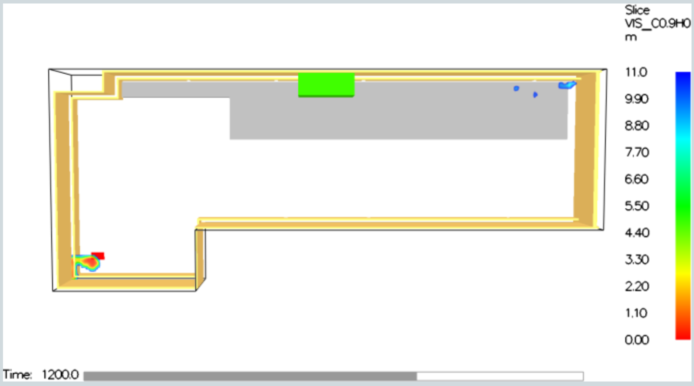
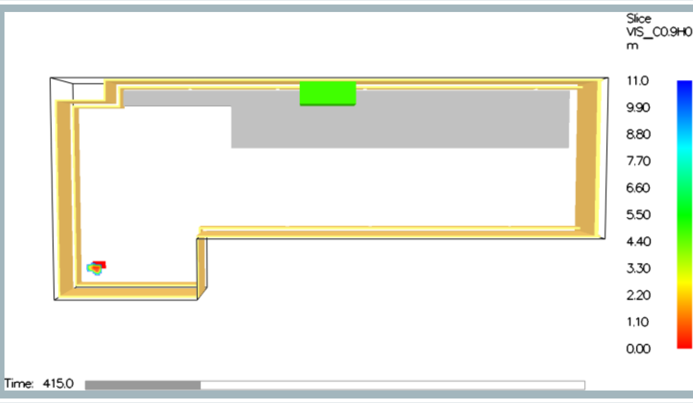
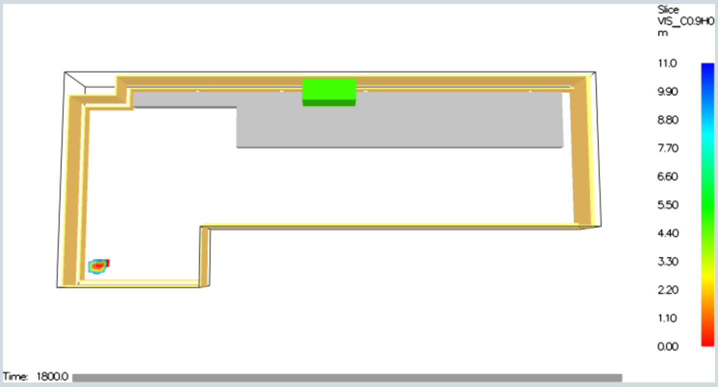
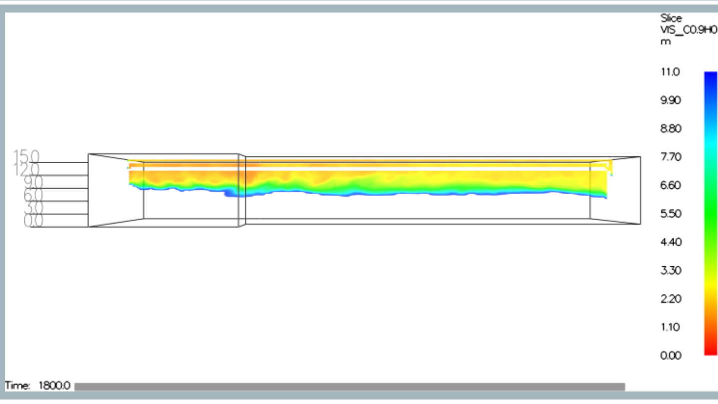
D.10 Conclusion

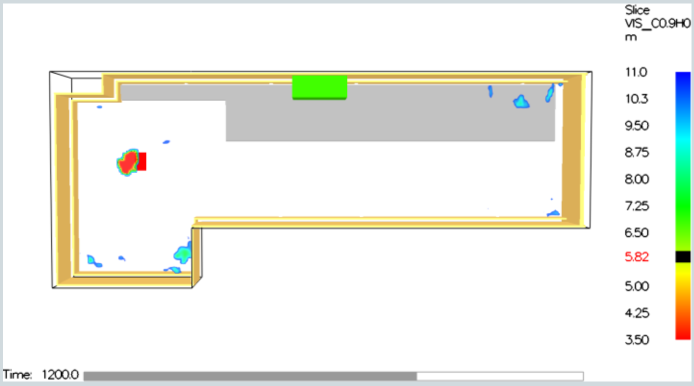
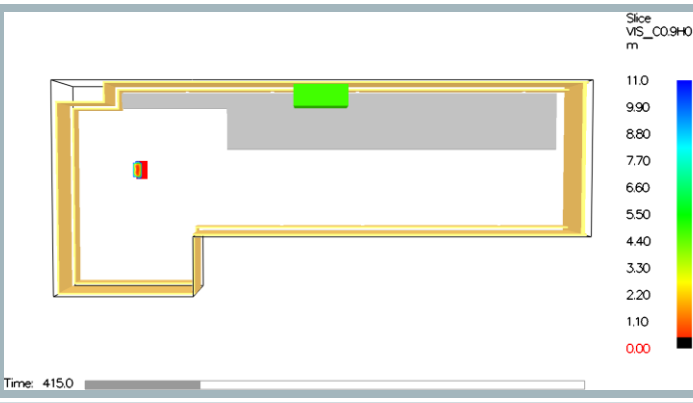
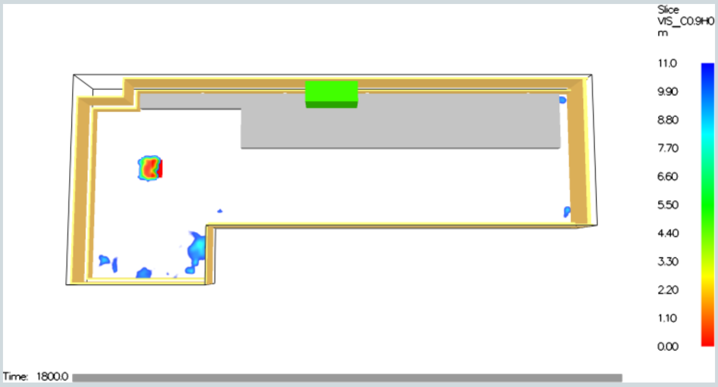
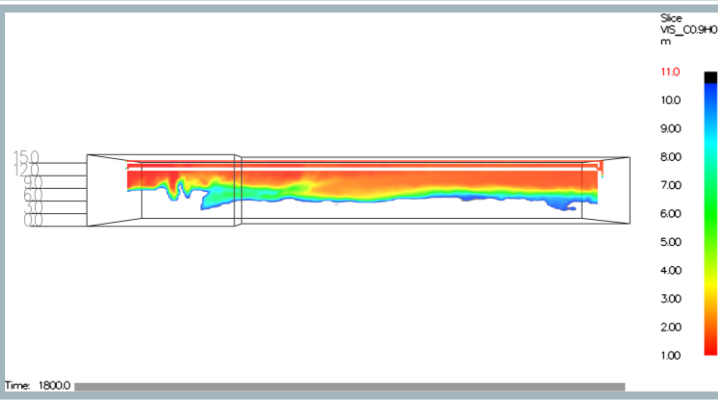
The results indicated that the fire scenarios met the acceptance criteria for identification of an elevated fire, occupant egress, and fire brigade intervention activities. Further analysis of specific scenarios established that the scenarios still indicated that the provided smoke hazard management system was sufficient to meet the intent established for the acceptance criteria.

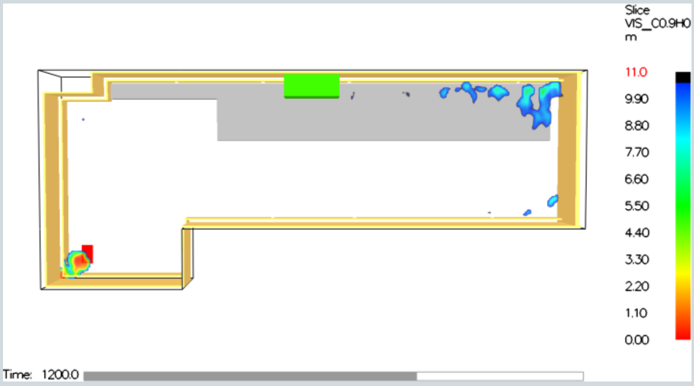
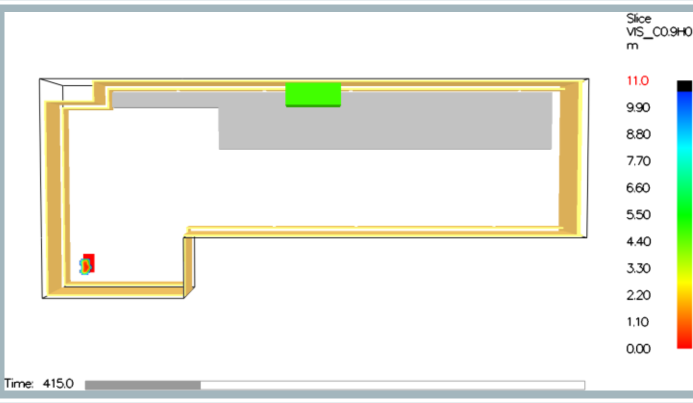
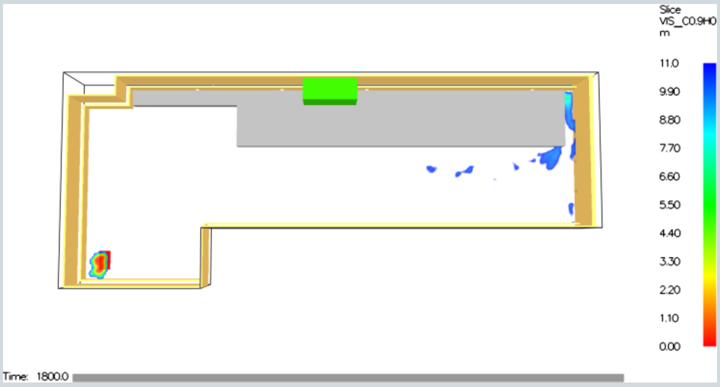
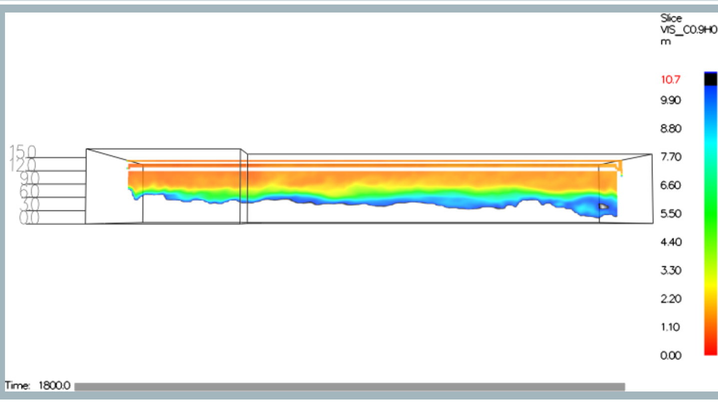
Therefore, the ridge vent smoke hazard management system proposed for 35-37 Frank St is anticipated to be sufficient to be capable of achieving the intervention criteria established by FRNSW.

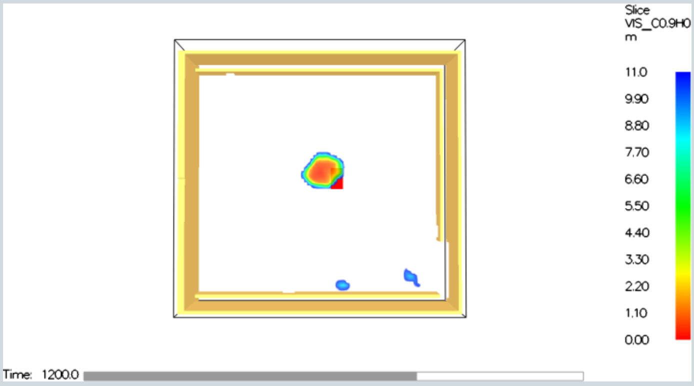
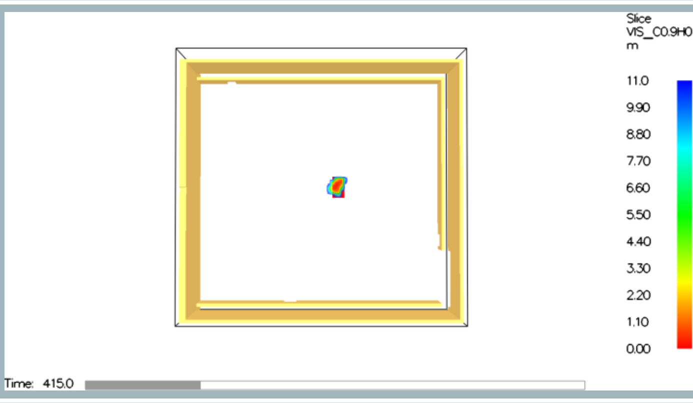
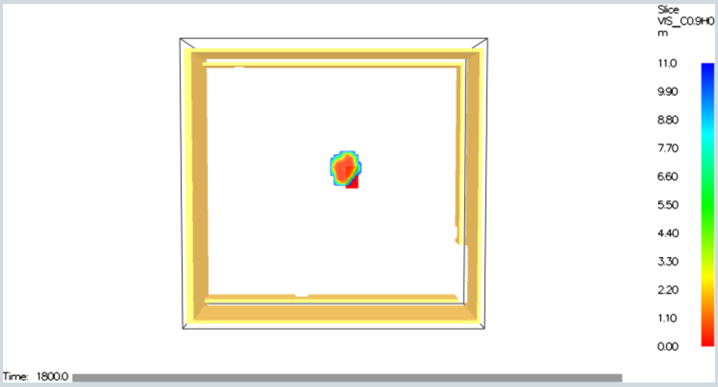
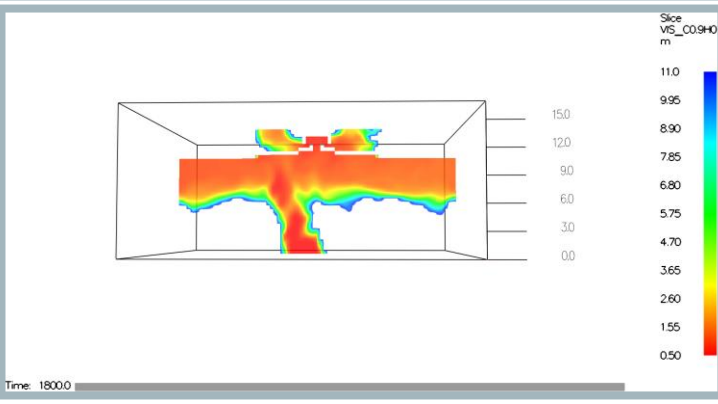
Appendix E Results/Slices: Special Hazard Scenarios

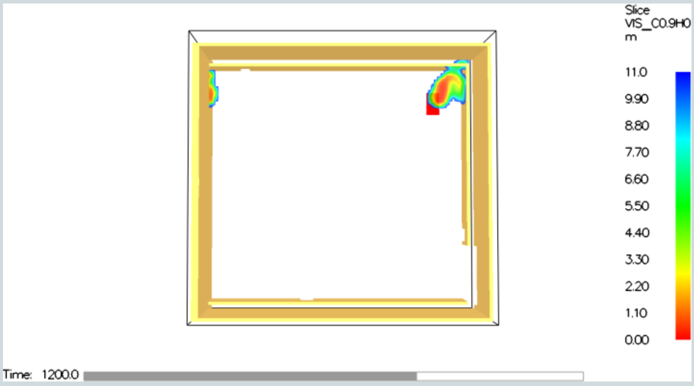
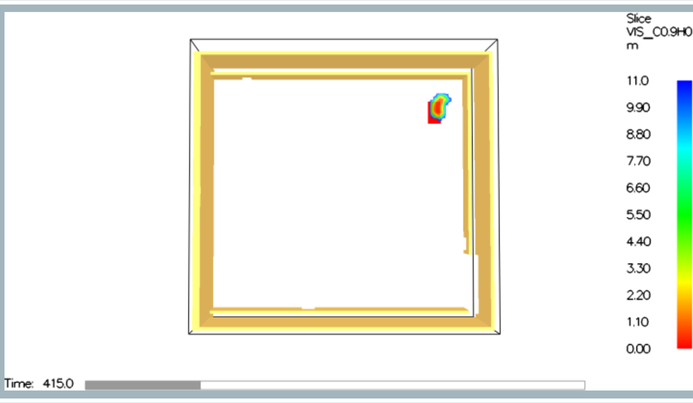
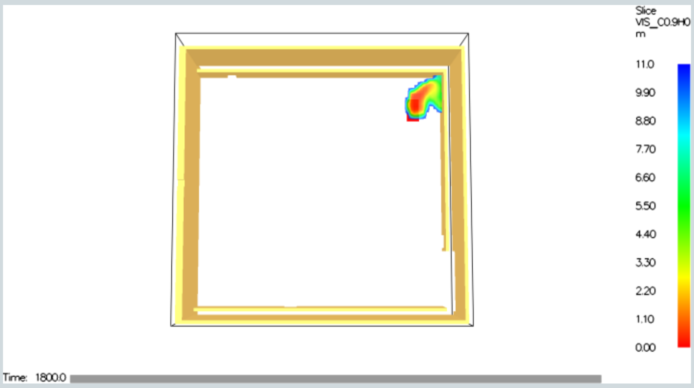
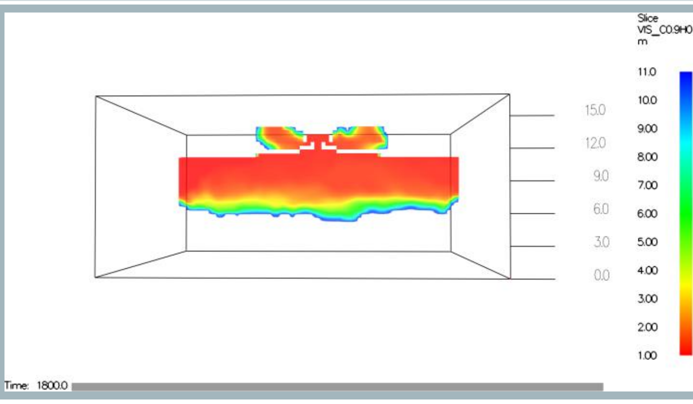
Scenario	#1: RAW Storage, First Row Activation, Centre Fire, Medium t² Growth rate
4 m Height **Smoke Visibility** **1200s**	
2 m Height **Smoke Visibility** **415s**	
2 m Height **Smoke Visibility** **1800s**	
Visibility Section **Length of Building** **1800s**	

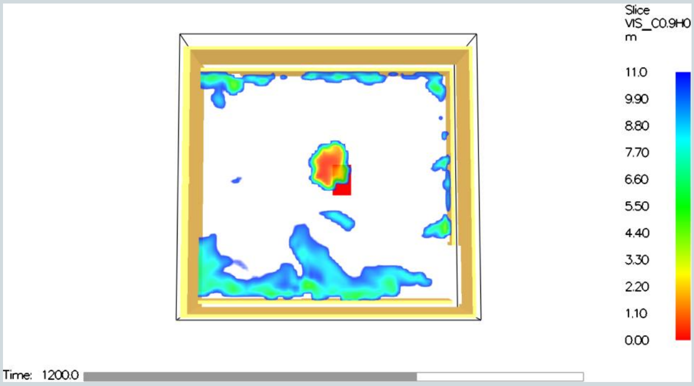
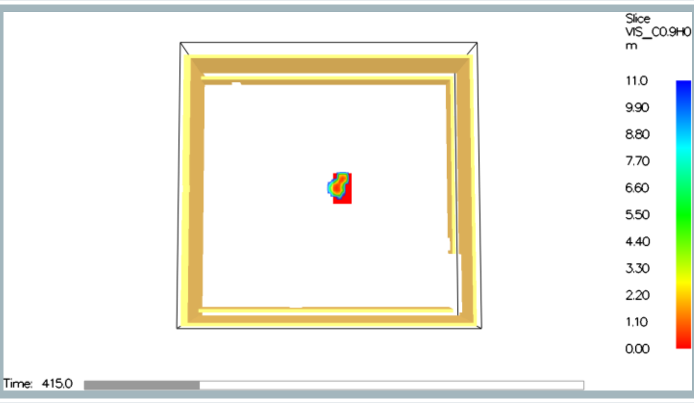
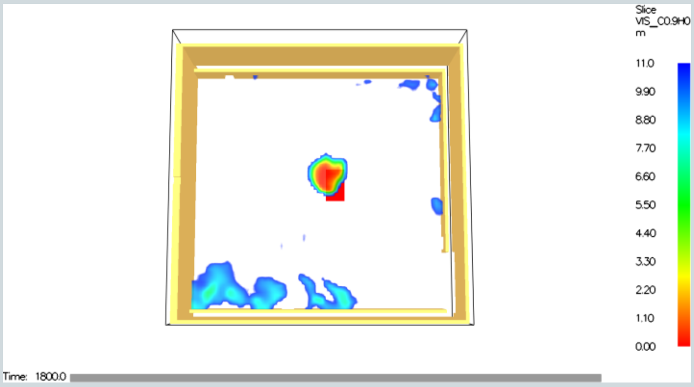
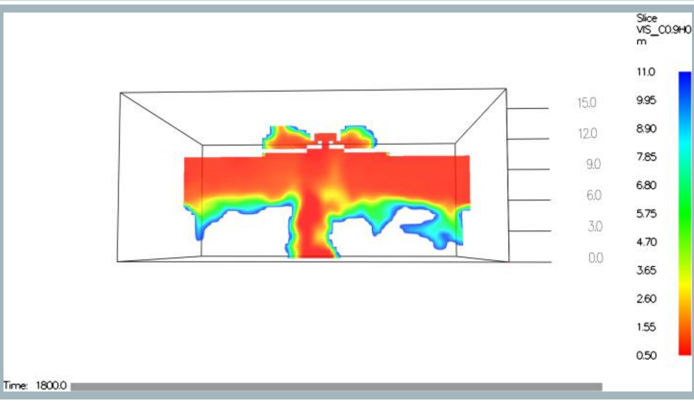
Scenario	#2: RAW Storage, First Row Activation, Corner Fire, Medium t² Growth rate
4 m Height **Smoke Visibility** **1200s**	
2 m Height **Smoke Visibility** **415s**	
2 m Height **Smoke Visibility** **1800s**	
Visibility Section **Length of Building** **1800s**	

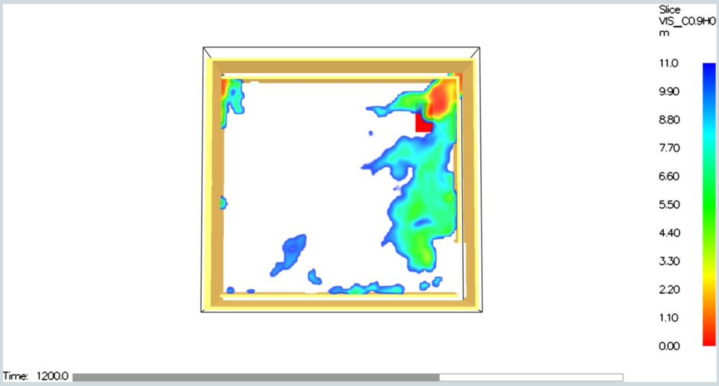
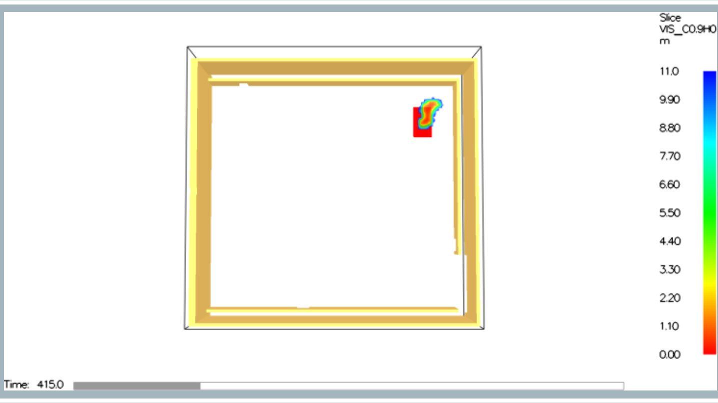
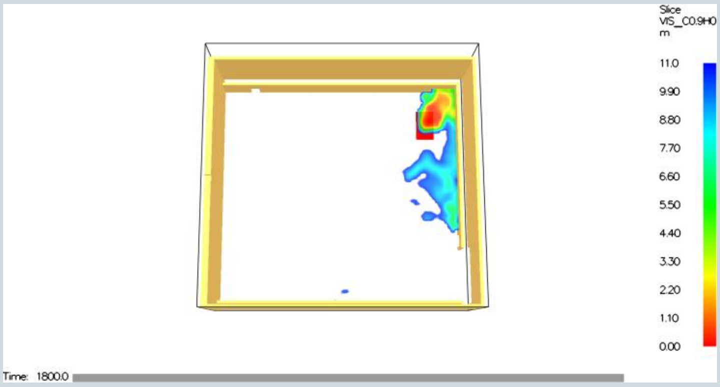
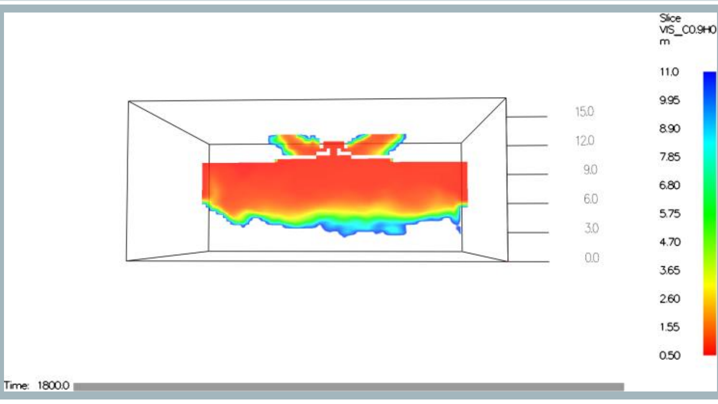
Scenario	#3: RAW Storage, Second Row Activation, Centre Fire, Medium t^2 Growth rate
4 m Height Smoke Visibility 1200s	
2 m Height Smoke Visibility 415s	
2 m Height Smoke Visibility 1800s	
Visibility Section Length of Building 1800s	

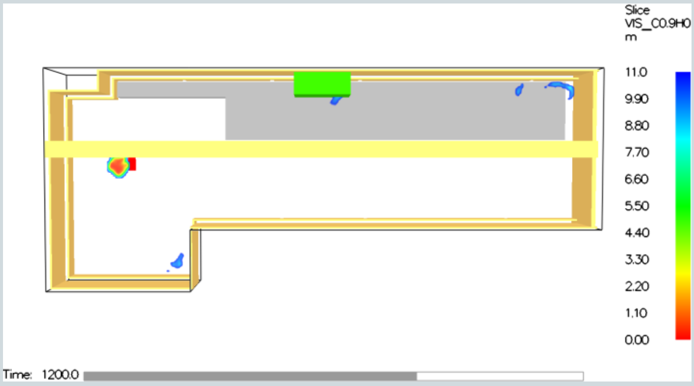
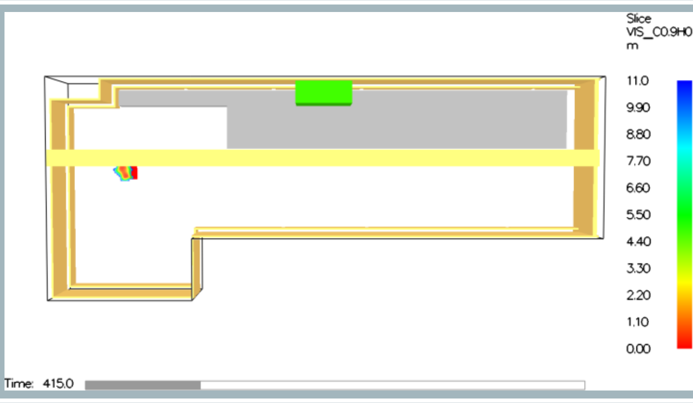
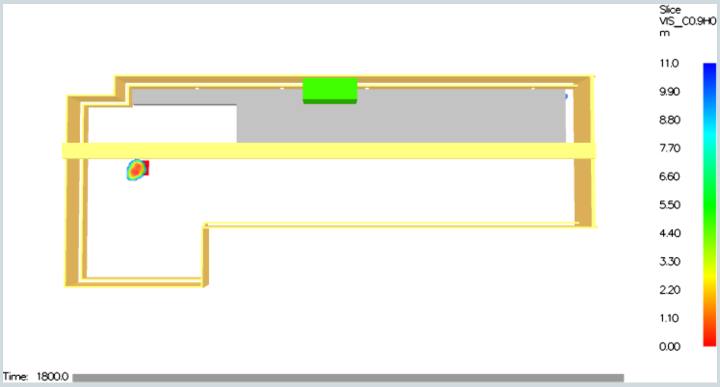
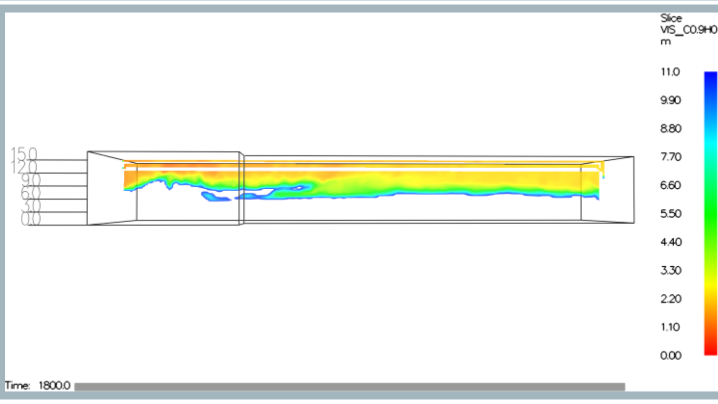
Scenario	#4: RAW Storage, Second Row Activation, Corner Fire, Medium t^2 Growth rate
4 m Height **Smoke Visibility** **1200s**	
2 m Height **Smoke Visibility** **415s**	
2 m Height **Smoke Visibility** **1800s**	
Visibility Section **Length of Building** **1800s**	

Scenario	#5: PEF Storage, First Row Activation, Centre Fire, Medium t^2 Growth rate
4 m Height **Smoke Visibility** **1200s**	
2 m Height **Smoke Visibility** **415s**	
2 m Height **Smoke Visibility** **1800s**	
Visibility Section **1800s**	

Scenario	#6: PEF Storage, First Row Activation, Corner Fire, Medium t² Growth rate
4 m Height **Smoke Visibility** **1200s**	
2 m Height **Smoke Visibility** **415s**	
2 m Height **Smoke Visibility** **1800s**	
Visibility Section **1800s**	

Scenario	#7: PEF Storage, Second Row Activation, Centre Fire, Medium t² Growth rate
4 m Height **Smoke Visibility** **1200s**	
2 m Height **Smoke Visibility** **415s**	
2 m Height **Smoke Visibility** **1800s**	
Visibility Section **1800s**	

Scenario	#8: PEF Storage, Second Row Activation, Corner Fire, Medium t² Growth rate
4 m Height **Smoke Visibility** **1200s**	
2 m Height **Smoke Visibility** **415s**	
2 m Height **Smoke Visibility** **1800s**	
Visibility Section **1800s**	

Scenario	#9: RAW Storage, First Row Activation, Centre Fire, Ultra-Fast t^2 Growth rate
4 m Height Smoke Visibility 1200s	
2 m Height Smoke Visibility 415s	
2 m Height Smoke Visibility 1800s	
Visibility Section Length of Building 1800s	

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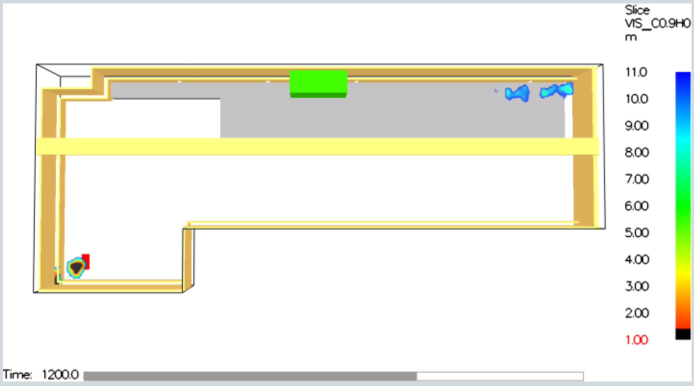
<tr><th>Scenario</th><th>#10: RAW Storage, First Row Activation, Corner Fire, Ultra-Fast t^2 Growth rate</th></tr>
<tr><td>4 m Height
Smoke Visibility
1200s</td><td>
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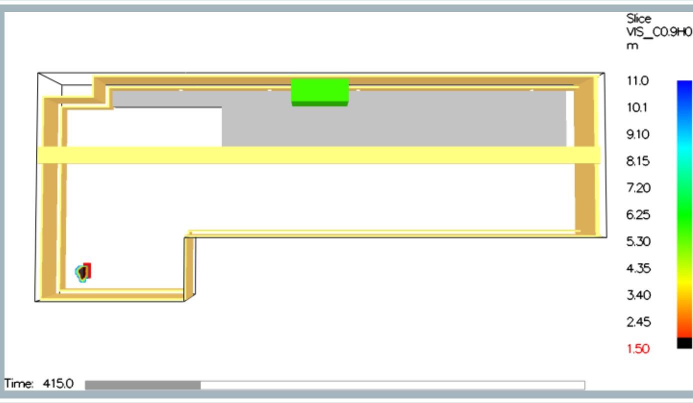
<tr><td>2 m Height
Smoke Visibility
415s</td><td>
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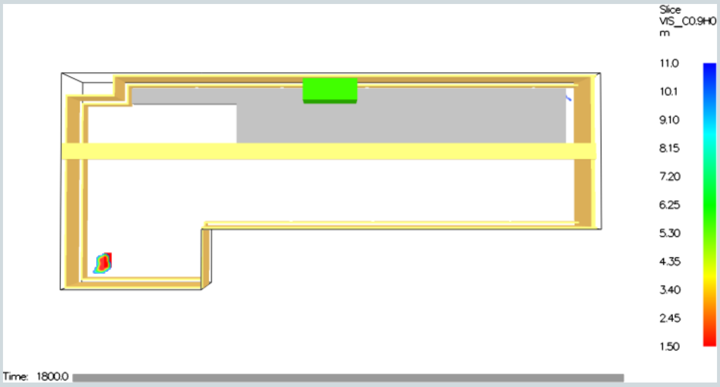
<tr><td>2 m Height
Smoke Visibility
1800s</td><td>
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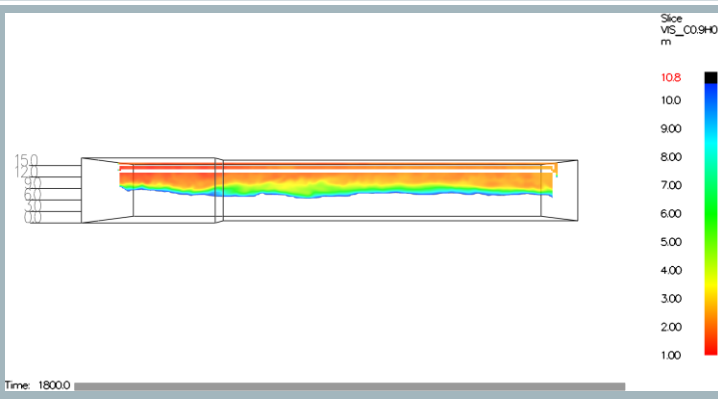
<tr><td>Visibility Section
Length of Building
1800s</td><td>
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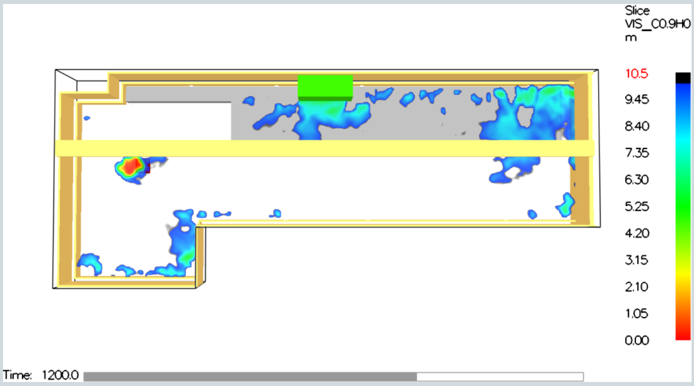
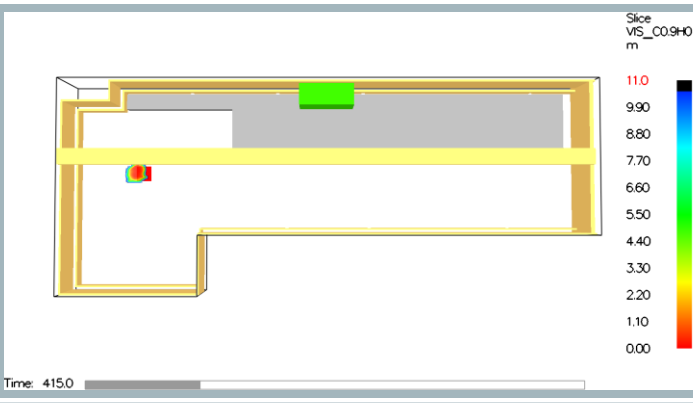
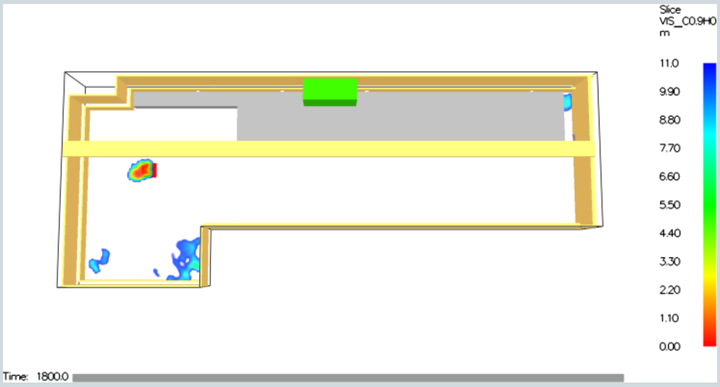
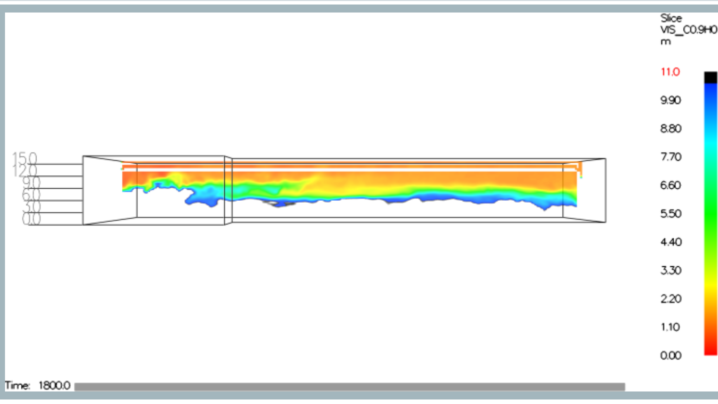
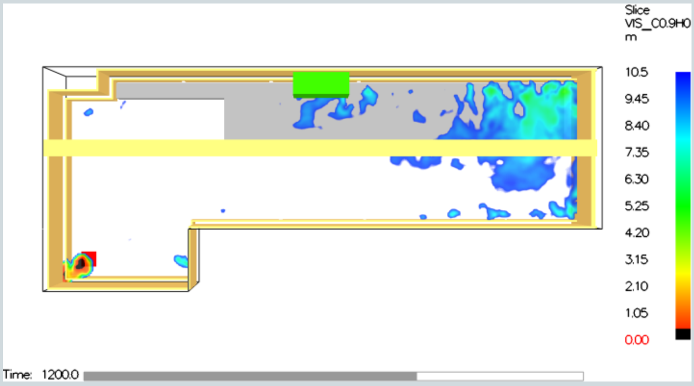
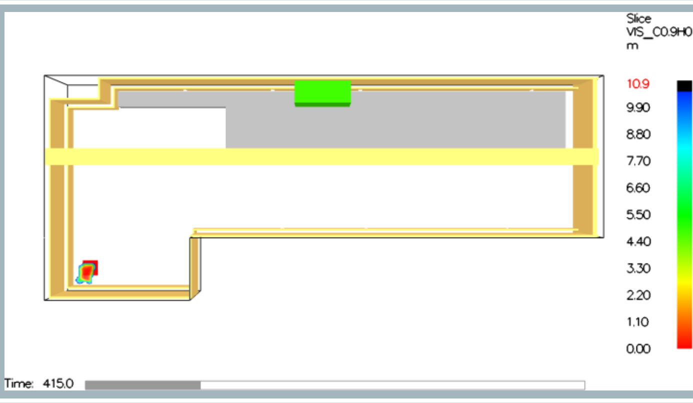
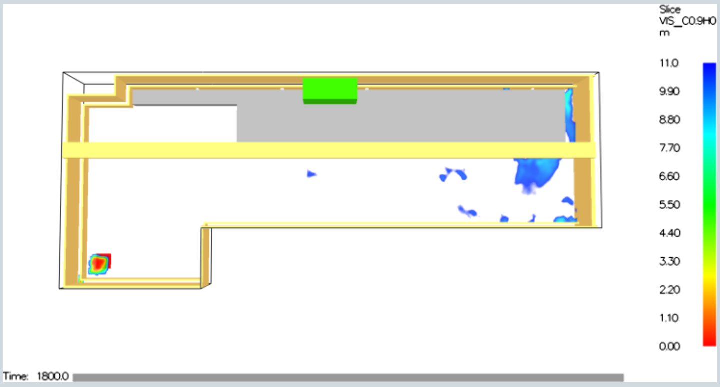
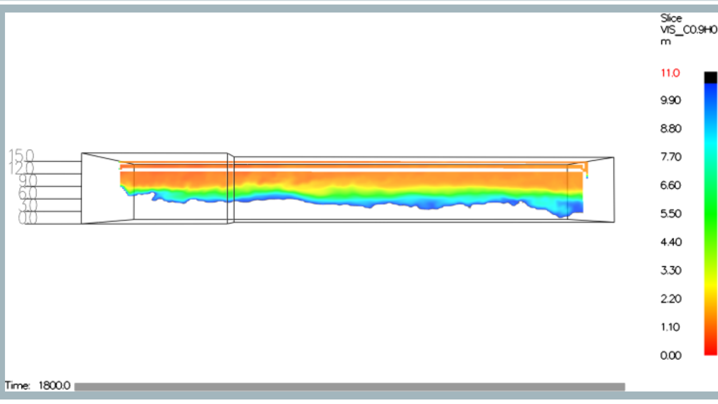
Scenario	#11: RAW Storage, Second Row Activation, Centre Fire, Ultra-Fast t² Growth rate
4 m Height **Smoke Visibility** **1200s**	
2 m Height **Smoke Visibility** **415s**	
2 m Height **Smoke Visibility** **1800s**	
Visibility Section **Length of Building** **1800s**	

Scenario	#12: RAW Storage, Second Row Activation, Corner Fire, Ultra-Fast t^2 Growth rate
4 m Height **Smoke Visibility** **1200s**	
2 m Height **Smoke Visibility** **415s**	
2 m Height **Smoke Visibility** **1800s**	
Visibility Section **Length of Building** **1800s**	

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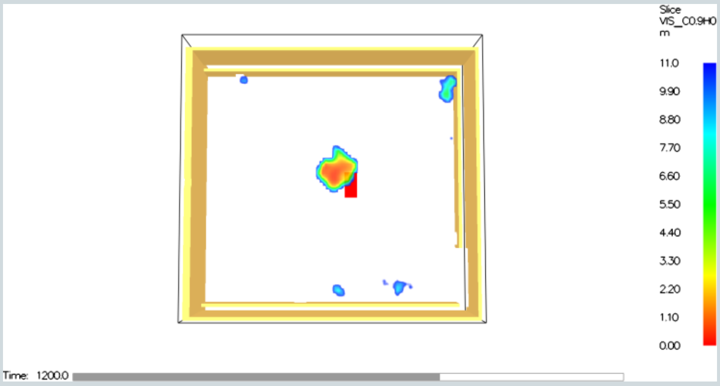
1200s</td><td>
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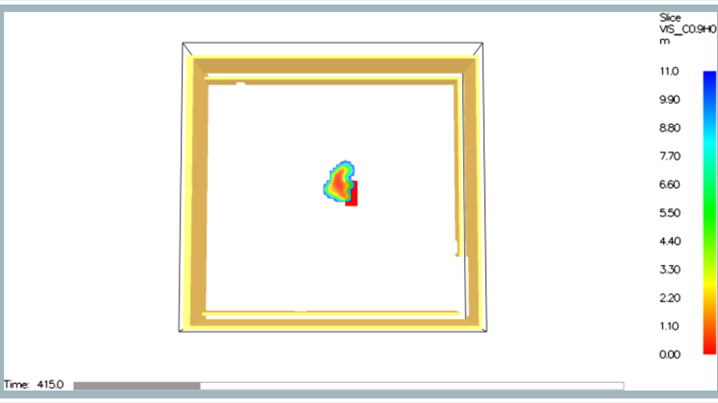
<tr><td>2 m Height
Smoke Visibility
415s</td><td>
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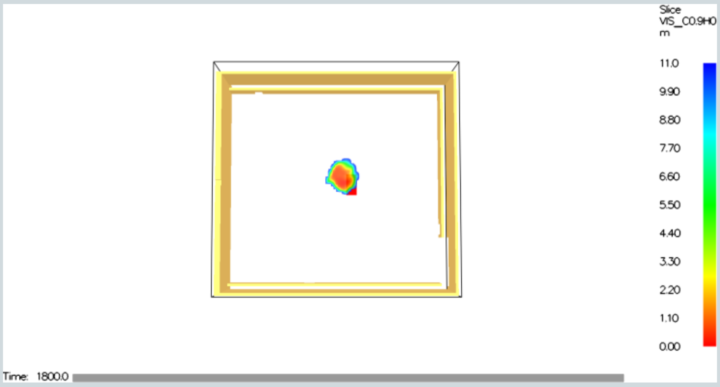
<tr><td>2 m Height
Smoke Visibility
1800s</td><td>
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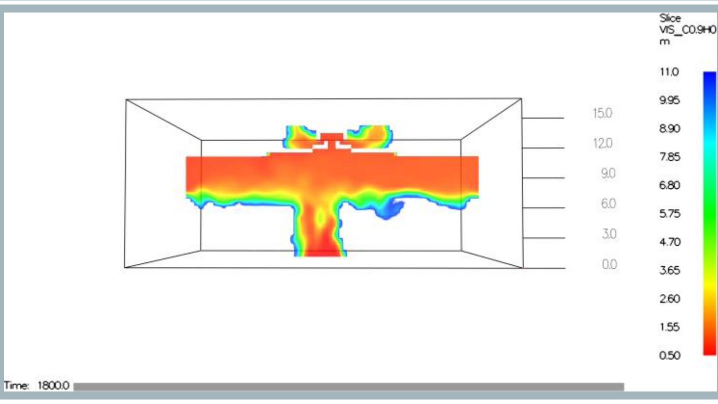
1800s</td><td>
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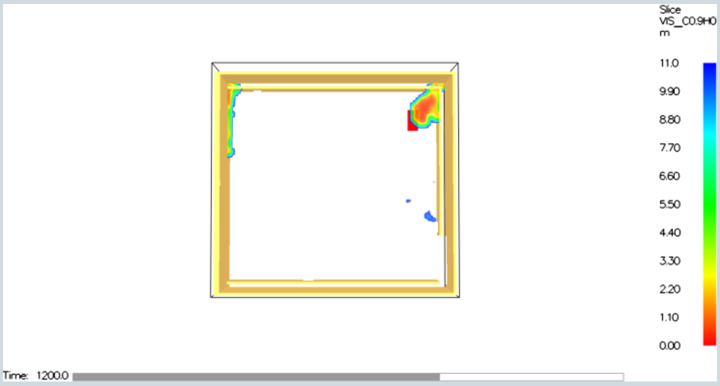
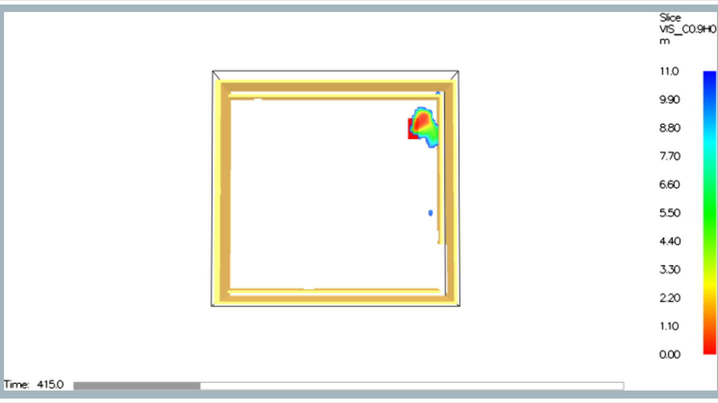
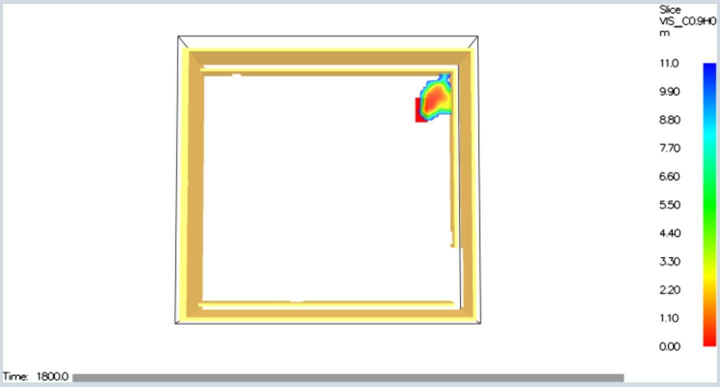
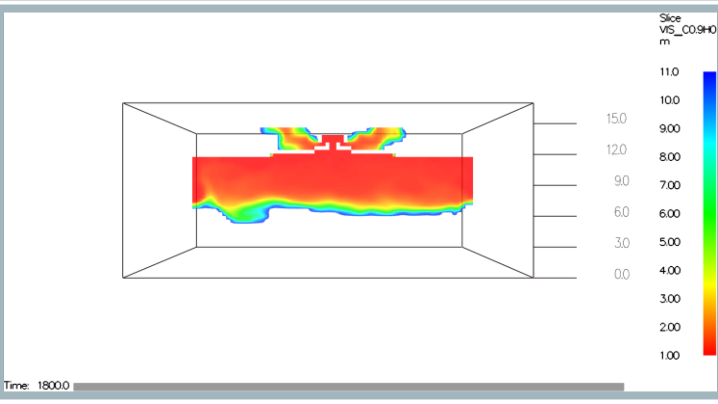
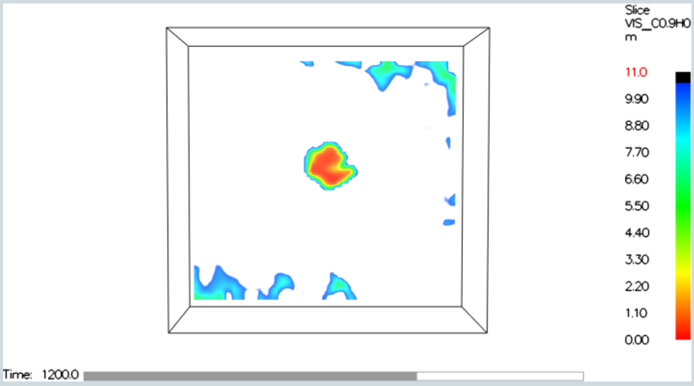
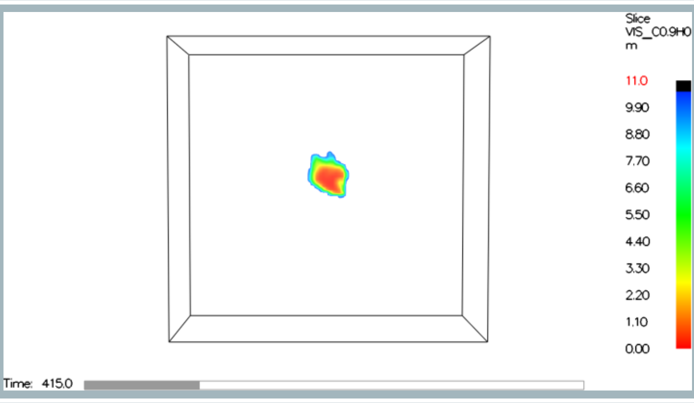
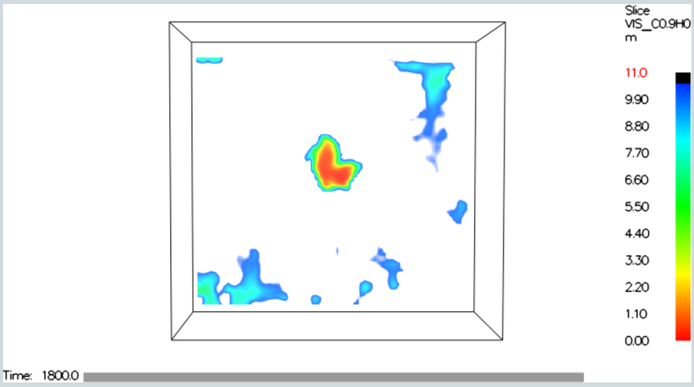
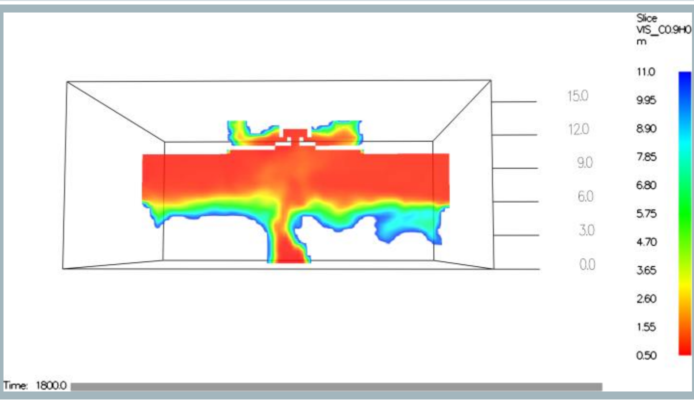
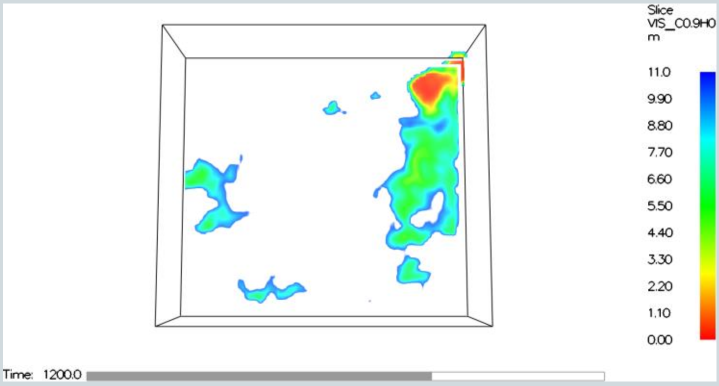
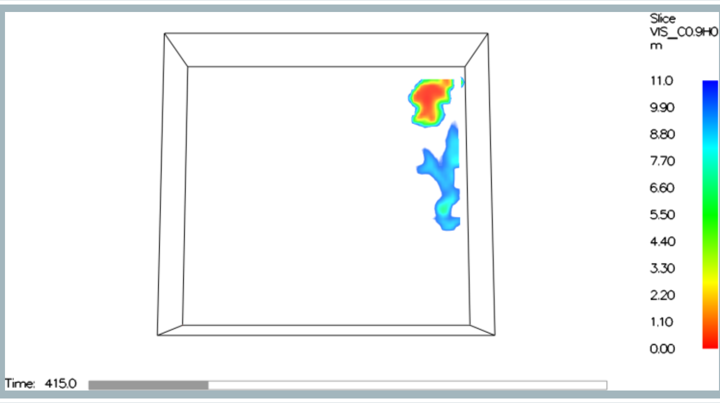
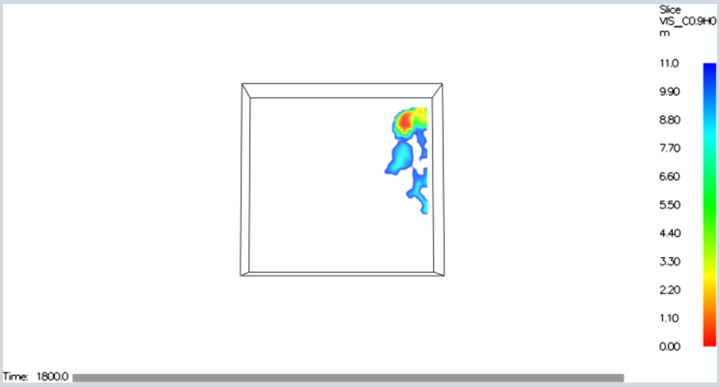
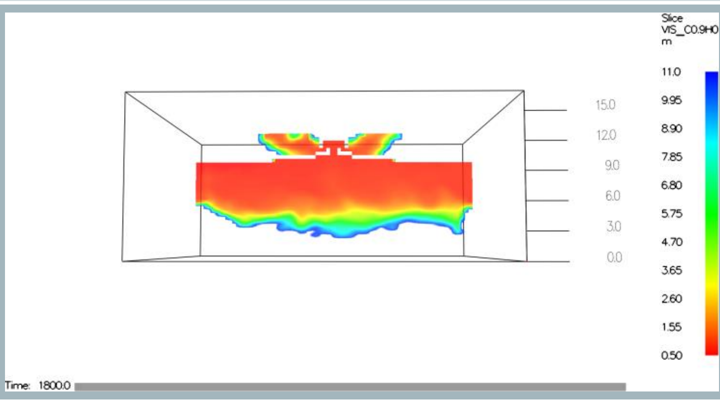
Scenario	#14: PEF Storage, First Row Activation, Corner Fire, Ultra-Fast t² Growth rate
4 m Height **Smoke Visibility** **1200s**	
2 m Height **Smoke Visibility** **415s**	
2 m Height **Smoke Visibility** **1800s**	
Visibility Section **1800s**	

Scenario	#15: PEF Storage, Second Row Activation, Centre Fire, Ultra-Fast t^2 Growth rate
4 m Height Smoke Visibility 1200s	
2 m Height Smoke Visibility 415s	
2 m Height Smoke Visibility 1800s	
Visibility Section 1800s	

Scenario	#16: PEF Storage, Second Row Activation, Corner Fire, Ultra-Fast t² Growth rate
4 m Height **Smoke Visibility** **1200s**	
2 m Height **Smoke Visibility** **415s**	
2 m Height **Smoke Visibility** **1800s**	
Visibility Section **1800s**	

Appendix F Special Hazard FRNSW Correspondence and Confirmation

F.1 FRNSW Feedback and Correspondence

The works provided above have been subject to FRNSW review, feedback and correspondence, which has been provided below to provide indication of FRNSW acceptance of the design, methodology and works regarding the Special Hazard provisions.

Colin Thomson

From:	Daire Fleming <Daire.Fleming@fire.nsw.gov.au>
Sent:	Tuesday, 26 September 2017 3:23 PM
To:	Colin Thomson
Cc:	Fire Safety; Trent De Maria; Steve Watson (SWatson@swpartners.com.au); Joshua Hawke (JHawke@swpartners.com.au); Giuseppe Gigliotti
Subject:	FW: Resource Co, Wetherill Park - CFD Modelling for Smoke Hazard Management CAN, Consultancy Advice Note 3.

Colin,

Following a review of the updated CAN 3 for 35-37 Frank Street, Wetherill Park (Resource Co) dated 6 September 2017 prepared by Olsson Fire & Risk (Ref S15332_CFD_CAN_03), FRNSW confirm that the proposal as detailed in this document is to FRNSW's satisfaction. FRNSW therefore consider suitable provisions for special hazards have been incorporated into the design in accordance with Condition A15 of the Development Consent issued on 10 April 2017 by the Minister for Planning (Application No. SSD 7256).

If you have any further queries regarding the above please do not hesitate to contact me.

Regards

Daire Fleming
Manager
Fire Safety Advisory Unit

Fire & Rescue NSW

E Daire.Fleming@fire.nsw.gov.au | **T** (02) 9742 7434 | **M** 0417 563 437 | **F** (02) 9742 7483 | **www.fire.nsw.gov.au**
Amarina Avenue, Greenacre, NSW 2190 | Locked Bag 12, GREENACRE, NSW 2190

From: Colin Thomson
Sent: Wednesday, 6 September 2017 5:41 PM
To: 'Daire Fleming' <Daire.Fleming@fire.nsw.gov.au>
Cc: Trent De Maria <Trent.DeMaria@olssonfire.com>; Steve Watson (SWatson@swpartners.com.au) <SWatson@swpartners.com.au>; Joshua Hawke (JHawke@swpartners.com.au) <JHawke@swpartners.com.au>; 'Giuseppe Gigliotti' <ggigliotti@ahrens.com.au>; Mark Castelli <Mark.Castelli@fire.nsw.gov.au>; 'Benjamin Hamilton' <Benjamin.Hamilton@fire.nsw.gov.au>
Subject: RE: Resource Co, Wetherill Park - CFD Modelling for Smoke Hazard Management CAN

Hello Daire,

Thank you for the review and comments. The updated CAN has been attached. If you find the updates and comments satisfactory, let us know and we will then proceed to integrate this into the Fire Engineering Report, along with the other matters that have been incorporated to address the special hazard provisions raised by FRNSW (namely, the stockpile size restrictions, hydrant upgrade, and water retention).

Please see my return comments and updates in blue.

Section 1.5 Demonstration of Results – FRNSW do not consider the statement that "tenability shall be considered to be met if at least 50% of the area achieves at least 10m visibility distances" as satisfactory. FRNSW consider that up to 50 % of the floor area not meeting the acceptance criteria means that the assessment has failed as the acceptance criteria is not met. Some small isolated areas may be acceptable, provided they are adequately justified, e.g. are not located at exit points and occupants would have the capability to move away from these areas prior to them becoming untenable. FRNSW would consider 5-10% of the floor area as a more appropriate figure.

Section 1.5 has been updated.

The acceptance criteria has been modified for the 2 m height and 4 m height profiles as the requirements for each are understood to be very different.

The 2m height acceptance criteria is set at not more than approximately 10% of the total area experiencing visibility below 10 m. Further, any obscuration of an exit shall subject the model to additional discussion and analysis in order to demonstrate that the loss of an exit will not be anticipated to obstruct occupant egress or fire brigade intervention.

The 4m acceptance criteria shall be demonstrated via one of two methods, method a) being a general method, and b) being a more specific method:
a) The acceptance criteria is considered to be met if no greater than 25% of the space, at 4 m above ground, experiences visibility < 10 m, by 1200 s. No further analysis in this case will be required.
b) In the event that a) is not demonstrated, the analysis shall detail that an elevated fire base is still provided with line of sight visibility for attending brigade officers from a height approximately 2 m above ground for a distance of at least 10 m.

At 4m above FFL, neither occupant or brigade safety is likely to be affected. 25% is taken to be a reasonable figure given that the sole purpose of the profile at this height is permitting fire fighters to visually locate the fire seat without any equipment (e.g thermal imaging).

Several scenarios trigger further analysis with this acceptance criteria @ 25%. In those cases, the analysis demonstrates that the obscuration does not affect a fire fighters ability at ground level to observe the fire seat.

Further, occupant egress assessments have been included. The Fire Engineering Report established an RSET of 415s, including travelling to an exit, finding it blocked, and travelling to an alternative exit, for redundancy. This time has been used to generate new slices at 2m. The ASET/RSET analysis for all scenarios meet the acceptance criteria for occupant egress.

FRNSW recommend that the egress routes and exit points should be kept tenable within the nominated ASET and any areas that drop below the acceptance criteria should be supported by analysis demonstrating that occupants are able to move away from these areas prior to them becoming untenable with the ability to reach an exit within the allowable travel distances be included. Similarly, the impact on fire brigade intervention also addressed.
The acceptance criteria in Section 1.5 has been updated to note egress routes/exit points as part of the discussion. As mentioned above, the ASET/RSET reflects the suitability of the design for occupants.

For brigade intervention times at 1800s, two scenarios indicate that one exit from the building *may* be partially obscured. The analysis has been updated to demonstrate that the provision of additional exits and other conservative factors in the design (e.g. no occupant intervention, no sprinkler suppression, no fire brigade PPE and no use of light emitting sources (which provide better results)) provide evidence of suitability of the design.

FRNSW refer to the following scenarios where there appears to be significant smoke spread around the perimeter of the building and question the justification of the statement above.
Scenario – 7, 11, 12, 14 and 15.
For these scenarios, smoke spread around the perimeter of the enclosure occurs at 4 m height, i.e. elevated, and is not anticipated to directly impact occupant egress or brigade intervention activities at a ground level. Additional discussion of the same has been provided to provide justification of the suitability of the design in these scenarios.

FRNSW recommend that the assessment further consider visibility at 4m height (the 5 m height criteria previous specified is to assist fire fighters in locating the seat of the fire to facilitate fire brigade intervention. Therefore, in this case if the storage is limited to a height of 4 m, then this height would be appropriate to use in this particular instance) to assess whether there is a significant improvement on current results.
Visibility slices at 4m height have been provided.

Best regards,

Colin Thomson **Fire Engineer**

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From: Daire Fleming [mailto:Daire.Fleming@fire.nsw.gov.au]
Sent: Tuesday, 20 June 2017 2:51 PM
To: Giuseppe Gigliotti <ggigliotti@ahrens.com.au>; Joshua Hawke (JHawke@swpartners.com.au) <JHawke@swpartners.com.au>
Cc: Benjamin Hamilton <Benjamin.Hamilton@fire.nsw.gov.au>; Trent De Maria <Trent.DeMaria@olssonfire.com>; Fire Safety <FireSafety@fire.nsw.gov.au>; Mark Castelli <Mark.Castelli@fire.nsw.gov.au>
Subject: RE: Resource Co, Wetherill Park - information's on stock piles

Hi Josh/Giuseppe

Further to our earlier telephone conversation regarding the implications of the smoke modelling timeframe upon the development's construction timeline. I highlight again that Fire & Rescue NSW (FRNSW) concerns in relation to Clauses E1.10 and E2.3 of the NCC and this development were provided to the Department of Planning & Environment on the 22 March 2016. Our concerns were reiterated on the 17 June 2016 in our email response to the Department regarding the Response to Submissions Report.

Notwithstanding the above, FRNSW are cognisant and empathetic to the project's timeline and our obligations with respect to the instrument of development consent (viz. the final design must to be approved by FRNSW prior to construction commencing). To expedite approval FRNSW will consider providing conditional interim approval of the following aspects of the development:

1. The proposed size and configuration of raw and unbaled PEF stockpile storages (i.e. three raw product stockpiles of a maximum size of 1000 m^3 each and 2 unbaled PEF maximum stockpiles of 825 m^3 each. Each stockpile separated from one another by fire rated bays of masonry construction). With two front end loaders available on-site with bucket capacities of 4.9m^3 each.
2. The fire hydrant system being supplied a minimum fire water supply rate of 40 litres per second.
3. The quantity of containment of contaminated fire water being confirmed as discussed at our recent meeting.

Should your client agree to implement the above requirements into the facilities design (by written confirmation) FRNSW will agree to the certifier issuing a staged construction certificate that excludes smoke hazard management pending FRNSW assessment of the smoke modelling results once they become available for our review and determination. We envisage that further discussions regarding smoke hazard management will need to occur to arrive at a mutually agreeable outcome and that an additional construction certificate will be required to be issued to incorporate the agreed outcomes. Please note however that the above proposal would need to be agreed to by Steve Watson & Partners as the principal certifying authority.

Regards

Daire Fleming
Manager
Fire Safety Advisory Unit

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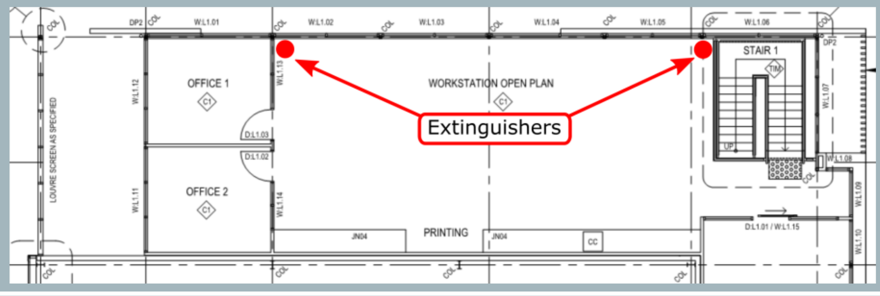
Appendix G Inspection Check List

Fire Safety Measure	Description	Observations During Inspection	Relevant Photo Thumbnail	Actions Arising
General	If not specifically mentioned the following fire safety measures are to be provided in accordance with the Deemed-to-Satisfy provisions. This includes the provision of: ▪ Automatic Fire sprinkler system (AS 2118.1-1999) – Manufacturing building only ▪ Automatic signalling equipment ▪ Building Occupant Warning System (1670.1-2015) – Manufacturing building only ▪ Emergency lighting and exit signs (AS 2293.1-2005) ▪ Fire hose reels (AS 2441-2005) ▪ Fire Hydrant System (AS 2419.1-2005) ▪ Portable fire extinguisher (AS 2444-2001) ▪ Statutory signage			
Construction Requirements	<u>Fire Resistance, Stability and Hazard Properties</u> In accordance with Part C of the BCA.	N/A		
Perimeter Vehicular Access	Perimeter vehicular access to the site is to be provided in accordance with BCA Clause C2.4, with the exception that gates at the entry to the site may be closed and passage of roadway will be over the transmission line easement. The following additional requirements are made: ▪ Gates and security checkpoints in the emergency vehicle travel path are to be secured with a loose chain and 003 type padlock or be provided with locking devices that can be unlocked by key (i.e. provided to the two nearest local fire stations) and be manually released or operated onsite (i.e. manual override). ▪ Hydrant valves are to be located clear of the transmission line easement. ▪ Any hydrant valves located within 10 m of the transmission line easement will have signage posted to be clearly visible to fire brigade personnel before operation of the hydrants. This sign will be similar to the sign below which is in accordance with WorkCover Code of Practice for Overhead Power Lines. This sign, or one similar, shall also be posted at each entry to the site.  ▪ The location of the transmission line easement is to be included on each block plan throughout the site (i.e. at the FIP, hydrant booster, and pump room).			
Fire hydrant system	A fire hydrant system shall be provided in accordance with BCA Clause E1.3 and AS 2419.1, with the additional FRNSW Special hazard requirement that the system shall be capable of supplying a minimum 40 L/s for at least 4 hours.			
Fire hose reels	Fire hose reels shall be provided in accordance with BCA Clause E1.4 and AS 2441.			

Fire Safety Measure	Description	Observations During Inspection	Relevant Photo Thumbnail	Actions Arising
Portable fire extinguishers	Portable fire extinguishers will be provided in accordance with BCA Clause E1.6 and AS2444. As per Section 5.3 of this report – two additional, multi-purpose Type ABE dry powder fire extinguishers (minimum 2.5 kg size) shall be provided to the first floor office area, in approximately the locations depicted below. 			
Fire sprinkler systems	A fire sprinkler system in accordance with AS2118.1 and BCA Clause E1.5 shall be provided throughout the manufacturing building. The response time index of the sprinklers shall not be greater than 50 $m^{1/2}s^{1/2}$.			
Building Occupant Warning System (BOWS)	A building occupant warning system in accordance with AS1670.1 shall be provided throughout the manufacturing building. Activation of the fire sprinkler system shall activate the building occupant warning system. Emergency manual call points in accordance with AS1670.1 shall be provided within the manufacturing building. The manual call points shall be white in colour and designed in accordance with the 'Emergency Warning' functionality of Clause 3.15 of AS1670.1 to activate the building occupant warning system only. These manual call points shall be distributed to the exits from the manufacturing building.			
Emergency lighting and exit signs	Emergency lighting and exit signage shall be provided in accordance with BCA Clause E4.2 and E4.5 respectively, and AS2293.1, with the exception that exit sign heights may be up to 4 m above the ground level in the manufacturing building. The extended height signs are to be 'Jumbo' signs.			
Management in use	An emergency management plan in accordance with AS 3745 shall be provided.	N/A		
Maintenance	A maintenance program shall be developed with all essential safety maintained in accordance with AS1851 and AS2293.2.	N/A		

Fire Safety Measure	Description	Observations During Inspection	Relevant Photo Thumbnail	Actions Arising

FRNSW Special Hazard Requirements	In addressing the Special Hazard provision of E1.10 and E2.3 as part of the Development Consent, the following fire safety measures are required by FRNSW (See Section 4.4 and Appendix F):
	▪ The stockpiles within the RAW and PEF areas shall be separated as follows:
	    ▪ The RAW area shall be divided into at least three (3) stockpile bays, of a maximum size of 1,000 m^3.
	    ▪ The PEF area shall be divided into at least two (2) stockpile bays, of a maximum size of 825 m^3.
	    ▪ Each stockpile shall be separated from one another by 120 minute fire rated bays of masonry construction. The separating construction shall be at least 2 m high.
	    ▪ The site shall maintain at least two (2) front end loaders on-site with bucket capacities of 4.9 m^3 each.
	▪ The site shall be capable of retaining contaminated fire water flowing for up to 90 minutes, equating to approximately 470,000 L, within the footprint of the building.
	▪ A ridge vent, running the length of the building at the highest point, shall be provided to meet the following requirements:
	    ▪ Minimum throat open diameter of 1,200 mm
	    ▪ Protected from wind via shielding for the length of the ridge vent, such that any inlet/discharge is not exposed to the horizontal movement of air or wind external to the building.
	    ▪ The ridge vent design shall meet or exceed the design exhaust capacity noted in Section D.6, Table 27.
	▪ Make-up air is to be provided by the dado-wall setback from the steel-clad wall by at least 500 mm, around the perimeter of the building.
	
	The roller shutter for the PEF storage area shall open upon sprinkler activation to provide additional make-up air and venting capabilities to the PEF area. Cabling to the roller shutters shall be in accordance with AS 1668.1.			