Final Fire Safety Engineering Report

creating intelligent fire safety solutions

Sydney
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Lot 202 Horsley Park, Logistic Park NSW

Project Address:	**10 Johnston Crescent, Horsley Park NSW**
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Prepared for:

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0. Executive Summary

0.1 General

This executive summary has been prepared to provide a concise statement of the Performance Solution issues identified and addressed in the assessment. The details of the Building Solution so assessed are described in full.

The purpose is to provide a readily accessible source to the intent and outcomes of the assessment with respect to the Building Solution presented.

The FSER is intended to represent a transparent account of the assessment process and outcomes consistent with the documented FEB process and reflects the discussions and agreements between SFS Australia Pty Ltd T/A Scientific Fire Services (SFS), the design team and the relevant authorities based on the information provided to date.

The Client is to ensure that the relevant stakeholders and services consultants that have been involved in the project are in agreement with the proposals made in this document. Furthermore it is the responsibility of the other designers and consultants (not SFS) to complete the detailed design of the various active and passive fire safety systems in accordance with the relevant design and installation Australian Standards and in accordance with the requirements listed in this report.

The reader should note the sections of this document that outline the scope of works, the assumptions and limitations and the fire safety objectives documented in this report. The building owner should be made aware of these sections of the FSER.

The executive summary must always be read in the context of the report as a whole.

0.2 Brief Building Description

The subject site is located at 10 Johnston Crescent, Horsley Park NSW whereby it is proposed to design and construct a Class 7b storage warehouse facility and associated Class 5 office/administration portions. The storage warehouse building is proposed to be sub-divided into four (4) tenancies as summarised below:

1. Warehouse A: 4,728m^2
2. Warehouse B: 2,454m^2
3. Warehouse C: 3,397m^2
4. Warehouse D: 3,156m^2

The building having a rise in storeys of not more than 2 (office portion) and a total floor area of approximately 16,513m^2. The building shall be treated as a *Large Isolated Building* and furthermore, shall be provided with automatic sprinkler protection throughout. Figure 0.2 illustrates the site layout.

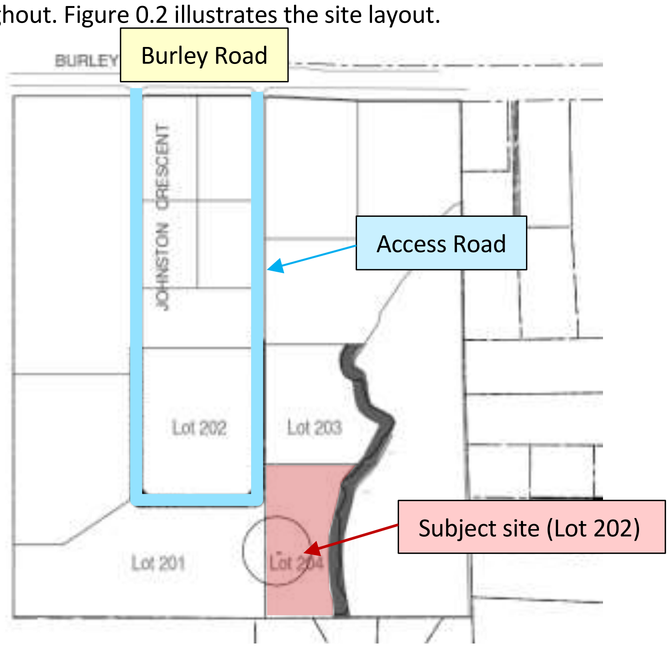


Figure 0.1: Key plan

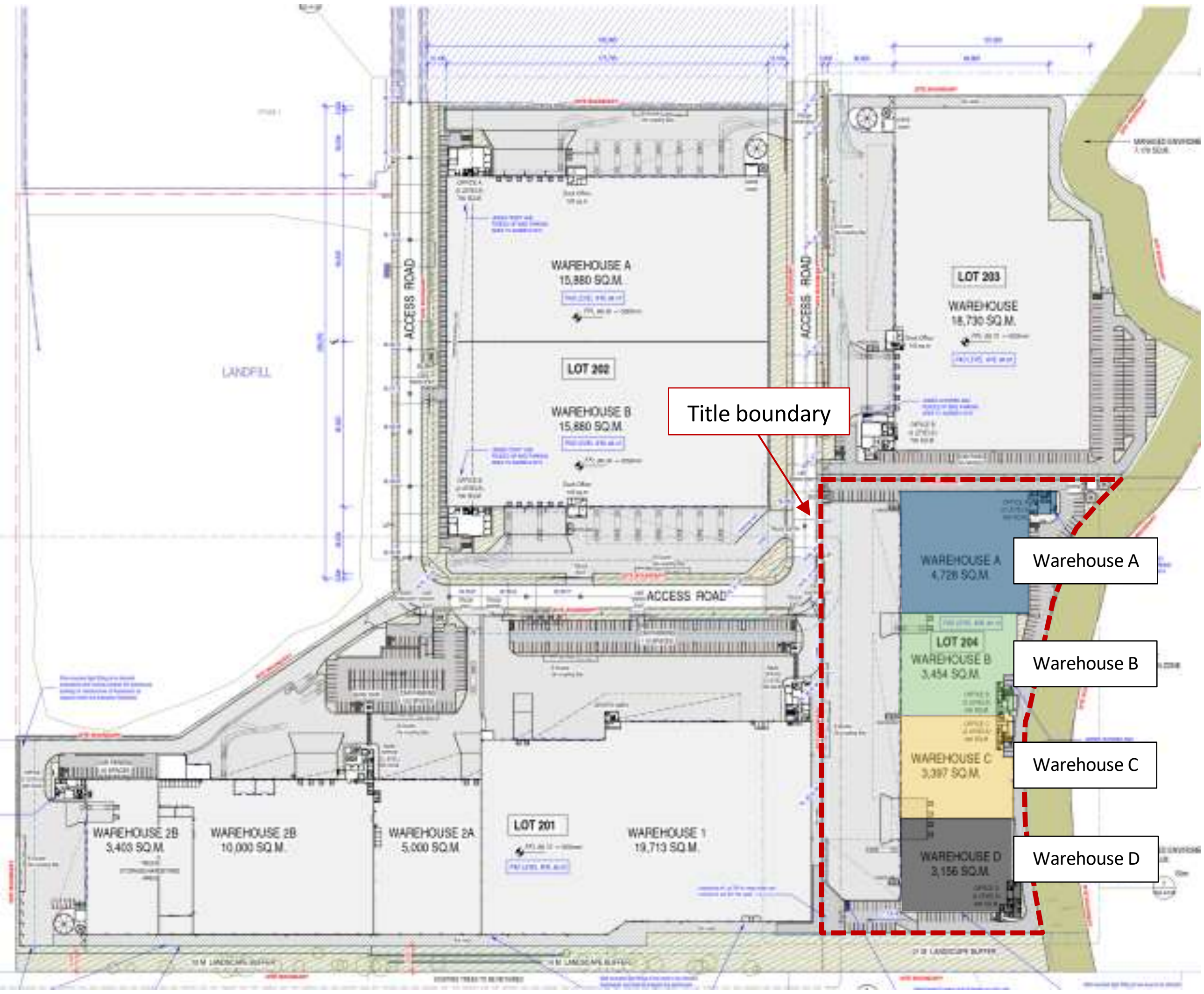


Figure 0.2: Site plan

Overall, the building shall comprise a rise in storeys of two (2) with a ridge height of up to 13.7m. As the volume of the proposed building exceeds the maximum volume limitation as permitted in Table C2.2 of Volume One of the NCC, the building has been classified as a 'Large Isolated Building' (LIB). The building is required by Clause C1.1 of the NCC to be constructed in accordance with Type C fire-resisting construction and shall be provided with an automatic sprinkler system incorporating storage sprinkler system in accordance with Clause E1.5 of Volume One of the NCC and AS2118.1:2017.

0.3 Building Design Issues and Performance Requirements

There are design issues that have been identified by McKenzie Group Consulting (NSW) Pty Ltd that represent deviations from the traditional prescriptive design requirements of the Volume One of the National Construction Code (NCC). Rather than seeking compliance with the more traditional 'Deemed-to-Satisfy' (DtS) provisions of the NCC a 'Performance Solution' has been formulated such that the identified design issues achieve compliance with the minimum level of compliance with the NCC namely the Performance Requirements of the NCC. The following table lists the identified design issues, the corresponding Performance Requirements, the methods of meeting the Performance Requirements and the Assessment Methods. It should be noted that the DtS provisions and Performance Requirements listed in the following table were identified by the Certifying Authority and agreed by relevant stakeholders.

Table 0.1: Identified Design Issues

Design Issue to be Addressed	NCC DtS Provision	Performance Requirement
It has been identified that the super awnings located along the western portion of the building form part of the external wall and are located within close proximity to the title boundary (within 3.0m) without the required fire rating pursuant to Type C fire resisting construction. It should be noted that the super awnings contain openings that are located within 3.0m from the title boundary.	Clause C1.1 inter alia Specification C1.1 & Clause C3.2 inter alia Clause C3.4	CP1 & CP2
The following design issues have been identified with respect to the proposed perimeter vehicular access serving the building: • The perimeter vehicular access is located more than 18m away from the external wall of the building (Warehouse A, B, C and D) due to the recess docks (i.e. up to 45m); and • Any perimeter fence gates (and gates forming part of the vehicular access) that are proposed to be locked are required to be fitted with suitable conventional padlocks to enable fire-fighter access with a standard key (i.e. 003 key locks). Alternatively, non-conventional padlocks are permitted provided access keys are provided to Fire & Rescue New South Wales (FRNSW) responding fire station stations.	Clause C2.3 inter alia Clause C2.4	CP9
It has been identified that the exit travel distance to one of the alternative exits and distance between alternative exits within the <u>warehouse portion</u> exceeds the maximum prescribed exit travel distances. More specifically: **Warehouse A** • To permit the distance of travel to designated exits of up to 45m in lieu of 40m; and • To permit the distance of travel between alternative exits of up to 85m in lieu of 60m. **Warehouse B** • To permit the distance of travel between alternative exits of up to 66m in lieu of 60m. **Warehouse C** • To permit the distance of travel between alternative exits of up to 63m in lieu of 60m. **Warehouse D** • To permit the distance of travel between alternative exits of up to 63m in lieu of 60m.	Clause D1.4 Clause D1.5	DP4 & EP2.2
It has been identified that the exit travel distance to an exit within the <u>office portion</u> exceeds the maximum prescribed exit travel distances. More specifically: **Office A** • To permit the distance of travel to designated exits of up to 30m in lieu of 20m. **Office B** • To permit the distance of travel to designated exits of up to 30m in lieu of 20m. **Office C** • To permit the distance of travel to designated exits of up to 30m in lieu of 20m.	Clause D1.4	DP4 & EP2.2
The fire hydrant system shall be designed and installed in accordance with AS2419.1:2005 with the exception of the following: • Permit the fire hydrant booster assembly to not be within sight of the main entry of the building; and • Permit fire hydrants without the requirement for fire rated shield panels throughout the entire site; and • Permit fire hydrants to be located beneath awning structures and furthermore, be designed to achieve external fire hydrant performance; – In this instance, fallback fire hydrants will be required providing coverage to the fire hydrant located beneath the awning/canopy structure; and • Permit fire hydrants coverage to be calculated based on Clause 3.5.3.3(b) of AS2419.1:2017, where the building parts receiving coverage are within 70m of the external fire hydrants.	Clause E1.3 inter alia AS2419.1:2005	EP1.3
It is proposed to permit the sprinkler booster assembly and pump room is not be located adjacent to the principal vehicular entry, at the site boundary and not within direct line of sight of the main entry to the building.	Clause E1.5 inter alia AS2118.1-2017	EP1.4

Design Issue to be Addressed	NCC DtS Provision	Performance Requirement
It is proposed to omit the provision of an automatic smoke exhaust system within the building. In this instance, it is proposed to permit a manually operated smoke clearance system having a smoke clearance capacity of 1 air change per hour per warehouse enclosure.	Clause E2.2	EP2.2
Directional and non-directional exit signs are to be installed throughout the building in accordance with Part E4 from Volume One of the NCC and AS2293.1:2018 with the exception that the mounting heights of exit signage within the warehouse storage portions of the building. In this instance, it is proposed to permit exit signs to be mounted 5.5m above the finished floor level within the warehouse portion only in lieu of 2.7m as required by the prescriptive provisions from Volume One of the NCC.	Clause E4.8 inter alia AS2293.1:2018	EP4.2

0.4 Methodologies

The following FSER has been undertaken generally in accordance with the International Fire Engineering Guidelines (IFEG) (ABCB, 2005). The assessment has considered the alternative solution to show compliance with the identified Performance Requirements of the BCA. The evaluation methodologies have been applied to demonstrate the Performance Requirements of the BCA Amendment 1 as allowed under Clause A2.2 are complied with. The analysis has been undertaken by qualitative and quantitative analysis and system assessments as allowed under Clause A2.4 of the BCA. Specific methodologies adopted in relation to the identified design issues are further detailed in the body of this report.

0.5 Fire Safety Measures

The building incorporates a range of fire safety measures in accordance with the relevant Australian Standards. In summary, the BCA defines the fire safety measures and their applicable standards required to be installed within the building. Unless otherwise stated, the applicable standard of fire safety system installation (active and passive) must be compliant with the BCA and the relevant Australian Standards.

The other fire safety system features which are specific to the performance solution proposed for this building are:

0.5.1 Fire Resistance and Type of Construction

1. Building elements throughout shall be constructed in accordance with the minimum Fire Resistance Level's (FRL's) commensurate with Type C fire-resisting construction; and
2. Separation of equipment shall be in strict accordance with Clause C2.12 from Volume One of the NCC; and
3. Any electrical substations within the building shall be separated from any other part of the building as required by Clause C2.13 from Volume One of the NCC; and
4. As required, building materials, components and structures shall be suitably tested and approved to achieve the test criteria consistent with AS1530.1:1994 in order to satisfy the DtS provisions of the NCC and/or AS1530.4:2014. All building elements which require an FRL shall be designed, prefabricated and installed in accordance with the tested and approved prototype; and
5. As required, building elements and passive systems (requiring an FRL) shall be suitably tested to meet the test criteria consistent with the minimum requirements prescribed by the DtS provisions of the NCC and/or AS1530.4:2014. All building elements which require an FRL shall be designed, prefabricated and installed in accordance with the tested and approved prototype; and
6. All parts of the building must be constructed in an appropriate manner using materials that are fit for purpose as well as being provided with evidence of suitability with respect to fire resistance and fire hazard properties to the satisfaction of the building certifier; and
7. All building lining materials and assemblies, both internal and external are required to meet the minimum fire hazard properties in Clause C1.10 and Specification C1.10 from Volume One of the NCC; and
8. Should any openings and/or penetrations be proposed, the FRL of the penetrating element shall be reinstated commensurate with the FRL required for the building element. Appropriately tested fire stopping protection methods shall be proposed to the openings/penetrations; and
9. To permit the non-loadbearing super awnings located along the western portion of the building form part of the external wall to be located within 3.0m from the title boundary without the required FRL specified under Table 5 of Specification C1.1. The identified super awnings shall be designed and constructed utilising materials and building elements deemed non-combustible when tested to AS1530.1:1994 or as per BCA Clause C1.12; and
   a. Permit the openings associated with the super awnings to be located within 3.0m from the title boundary; and

b. Further to the above, the perimeter vehicular access road on the reverse side of the title boundary achieves a minimum clear width of 6.0m; and

c. The non-loadbearing super awnings is sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 to 'Ordinary Hazard 3' classification unless otherwise Storage Sprinklers are proposed.

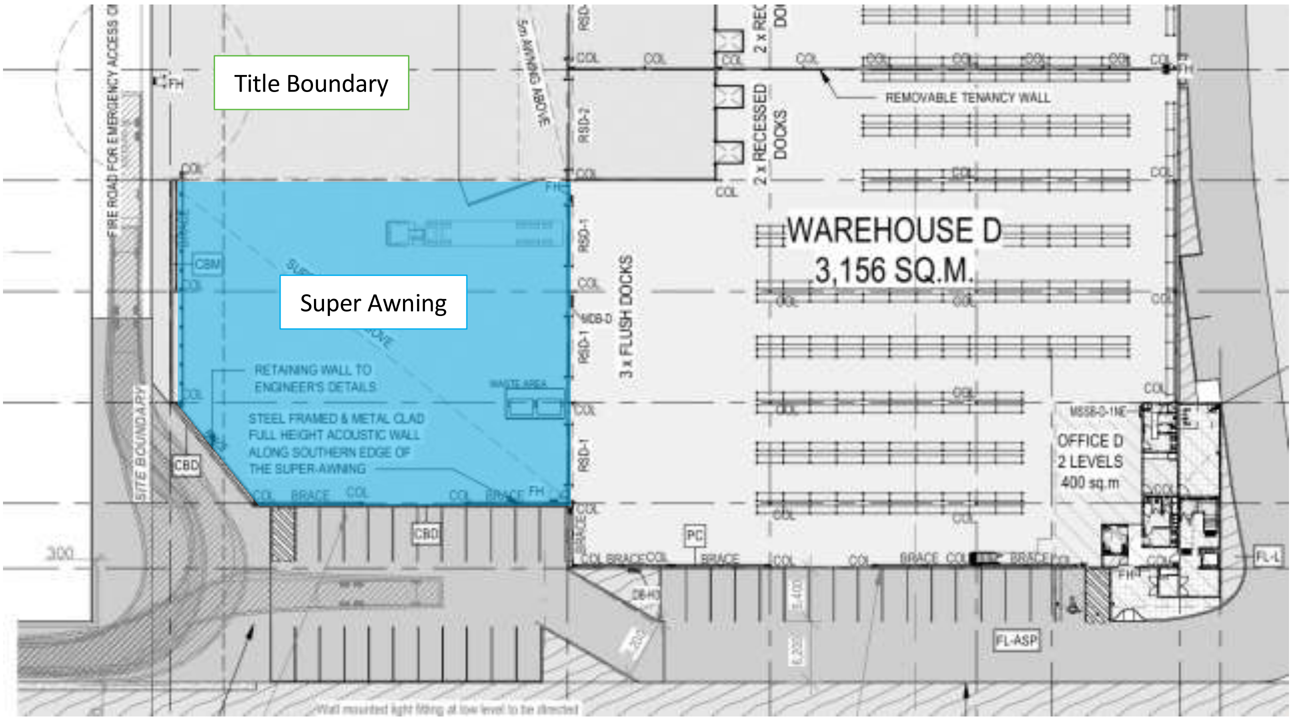


Figure 0.3: Location of super awning and the 6.0m wide perimeter vehicular access road on the reverse side of the title boundary

0.5.2 Occupant Egress Provisions

1. Egress provisions must comply with Part D from Volume Once of the NCC serving the <u>Class 7b warehouse storage</u> portions with the exception of the following:

   Warehouse A

   a. To permit the distance of travel to designated exits of up to 45m in lieu of 40m; and

   b. To permit the distance of travel between alternative exits of up to 85m in lieu of 60m.

   Warehouse B

   a. To permit the distance of travel between alternative exits of up to 66m in lieu of 60m.

   Warehouse C

   a. To permit the distance of travel between alternative exits of up to 63m in lieu of 60m.

   Warehouse D

   a. To permit the distance of travel between alternative exits of up to 63m in lieu of 60m.

2. Egress provisions must comply with Part D from Volume Once of the NCC serving the <u>Class 5 office</u> portions with the exception of the following:

   Office A

   a. To permit the distance of travel to designated exits of up to 30m in lieu of 20m.

   Office B

   a. To permit the distance of travel to designated exits of up to 30m in lieu of 20m.

   Office C

   a. To permit the distance of travel to designated exits of up to 30m in lieu of 20m.

3. All emergency exit doors which may be locked due to security requirements are to open on General Fire Alarm (GFA) and/or power failure.

0.5.3 Fire Services and Equipment

1. The entire building shall be provided with automatic fire sprinkler protection in accordance with AS 2118.1:2017. The sprinkler system shall be as follows:

   a. The Class 5 office portion of the subject building is to be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 appropriate to 'Light Hazard' classification; and
   b. The Class 7b warehouse portion of the subject building is to be sprinkler protected with the installation of K22 Storage Sprinkler or equivalent incorporating 'fast response' type heads. The activation temperature of Storage sprinkler heads shall be no more than 101°C; and
   c. Covered awnings forming part of the Class 7b portion of the subject building shall be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 to 'Ordinary Hazard 3' classification unless otherwise Storage Sprinklers are proposed; and
2. Where required, the Storage Sprinkler system shall comply with the Factory Mutual (FM Global) Property Loss Prevention Data Sheet 2-0, "Installation Guidelines for Automatic Sprinklers" and Property Loss Prevention Data Sheet 8-9, "Storage of Class 1, 2, 3, 4 and Plastic Commodities." The design and installation of the Storage Sprinkler system shall be in strict accordance with the building geometry/height, achieve required minimum clearance, commodity/storage layout/height & hydraulic pressure/flow requirements; and
3. Permit the sprinkler booster assembly and pump room are not be located adjacent to the principal vehicular entry, at the site boundary and not within direct line of sight of the main entry to the building:
   a. Provide site wide block plans which can be readily seen by FRNSW upon arrival to the site from Johnston Crescent. The block plans shall be weatherproof engraved A1 size illustrating all buildings onsite as well as key fire services (incl. fire hydrant booster location, fixed onsite fire pump sets, sprinkler booster assembly, main FIP location, static fire water tanks, vehicular access road etc.); and
4. The automatic fire sprinkler system must be interconnected to the Building Occupant Warning System (BOWS serving all tenancies within the subject building); and
5. The Building Occupant Warning System (BOWS) shall actuate upon activation of the automatic sprinkler system. The BOWS shall initiate a General Fire Alarm (GFA) throughout the building and hence achieve sound pressure levels in accord with AS1670.1:2018; and
6. Smoke detection shall be provided within the office portions only in accordance with Specification E2.2b and AS1670.1:2018 designed and installed on a spacing of no more than 15m x 15m which shall activate the BOWS throughout; and
   a. Each enclosure within the office portion shall be provided with no less than one (1) detector. This requirement does not apply to enclosures which contain a shower; and
7. The main Fire Indicator Panel (FIP) shall be located within the main entry of Office Warehouse A; and
8. Installations activating the BOWS shall also be connected to a fire alarm monitoring system connected to a fire station or fire station despatch centre in accordance with AS1670.3:2018; and
9. Omit the requirement to provide automatic smoke exhaust system and associated smoke baffle and automatic smoke detection system throughout the building; and
10. The building shall be provided with smoke clearance system, to the degree necessary, to allow a degree of smoke and hot gas venting from the warehouse portions of the building. In this instance, the smoke clearance system shall can be achieved via a manually operated smoke clearance fan system as per the following:
    a. Manual Operation (dedicated fire mode system for smoke clearance – fire brigade use only); and
       i. Manually operated smoke clearance fan(s) system shall be operable by means of activating a 'toggle switches or push button devices' located at the main Fire Indicator Panel (FIP) location; and
       ii. A single manually operated smoke clearance toggle switches shall be provided for each tenancy; and
       iii. The warehouse shall have the capacity to vent a minimum of one (1) air change per hour throughout each warehouse tenancy; and
       iv. Provide additional signage at each sub-fire indicator panel (SFIP) to notify fire crews of the manual toggle switch configuration is located at the main Fire Indicator Panel (FIP). The signage shall be A4 size, in capital letters no less than 50mm in height, in colour contrasting with the background and stating the following (or similar equivalent):

          "SMOKE CLEARANCE FAN CONTROLS AT THE FIRE INDICATOR PANEL IN MAIN ENTRY OF OFFICE WAREHOUSE A"

       v. Designed and installed in accordance with Specification E2.2b with regards to the componentry such as control gear, wiring and operation temperature (i.e. 200°C for a period of 1 hour); and
       vi. Designed and installed with power supply wiring to the smoke clearance fan infrastructure must comply with AS1668.1:2015; and
    b. Make up air provisions shall be evenly distributed, situated at low level and must have a sufficient area size such that one (1) air change to each tenancy part of the building is achieved. The make-up air provisions may be provided via perforated doors/ RSD's or a combination of both, which must be positioned/located below

the smoke layer height. The height of the make-up air openings has been provided by the mechanical engineer; and

   i. Where RSD's are proposed to be used for make-up air provisions, the RSD's are required to be hardwired to the FIP and be configured to automatically open when the toggle switches for the smoke clearance system are activated by fire-fighting personnel; and

11. Fire hydrants are to be located and installed in accordance with NCC Clause E1.3 and AS2419.1:2005 with the exception of the following:
    a. Permit the fire hydrant booster assembly to not be within sight of the main entry of the building; and
    b. Permit fire hydrants without the requirement for fire rated shield panels throughout the entire site; and
    c. Permit fire hydrants to be located beneath awning structures and furthermore, be designed to achieve external fire hydrant performance;
    d. Provide additional external 'fall back' hydrant(s) to facilitate operations such that fire-fighters are able to utilise the fire hydrants located beneath the covered awnings (refer to Figure 13.1 for further details). The external 'fall back' fire hydrants are to be located within 60m if the fire hydrants located beneath the covered awnings, be located as close as possible to the perimeter vehicular access location and furthermore are to be design and installed to achieve attack fire hydrant performance; and
    e. Permit fire hydrants coverage to be calculated based on Clause 3.5.3.3(b) of AS2419.1:2017, where the building parts receiving coverage are within 70m of the external fire hydrants.
12. The fire hydrant pump room is deemed to be located internal to the building. Therefore, the requirements for the pump room must strictly be in accordance with Clause 6.4.2 from aS2419.1:2005 with respect to the bounding construction of the pump room enclosure and location of doorways leading to open space; and
13. Each fire hydrant outlet shall be provided with a localised block plan (A3 minimum & weather fade resistant) to pictorially and numerically illustrate the next available alternative hydrant outlets; and
14. Any electrical substation(s) and/or Main Switch Board(s) (MSB) proposed for the site shall be situated no less than 10m from the fire hydrant booster assembly; and
15. The fire hydrants in the proposed fire hydrant system are to be accessible for use by Fire & Rescue NSW (i.e. clear paths of travel); and
16. All on-site fire hydrants are to be fitted with Storz hose couplings which comply with Clause 7.1 of AS2419.1:2005. This clause states in part "hose couples shall be compatible with those used by the fire brigade serving the area". Storz hermaphrodite fire hose couplings must be fitted to all fire hydrants and the fire hydrant booster assembly connections as required by Appendix E of AS2419.1:2005. The Storz fittings must be manufactured to DIN 14303, aluminium alloy delivery couplings, in accordance with Appendix A of AS2419.2-1994. Blank caps must be provided in accordance with Clause 2.8 of AS2419.2-1994; and
17. Block plans are to be provided at the main Fire Indicator Panel (FIP) and all sub-fire indicator panels (SIP's), fire hydrant booster assembly and sprinkler booster assembly in accordance with the FRNSW Fire Safety Guideline – Emergency Services Information Package and Tactical Fire Plans (Version 02, dated 07/01/2019); and
18. Fire hose reel system shall be designed and installed in accordance with Clause E1.4 from Volume Once of the NCC and AS2441:2005; and
19. Portable fire extinguishers shall be selected and mounted in accordance with Clause E1.6 from Volume One of the NCC and AS2444:2001; and
20. Exit signs and directional exit signs are to be installed throughout all buildings in accordance with Clauses E4.5, E4.6 and E4.8 from Volume One of the BCA and AS2293.1:2018 with the exception that the mounting heights of exit signage within the warehouse portions of the buildings. The directional and non-directional exit signs are to be "JUMBO" signs and furthermore, shall be mounted 5.5m above the finished floor level measured to the top of the exit sign within the warehouse portion only in lieu of 2.7m as required by the prescriptive provisions from Volume One of the BCA; and
21. Exit signs and directional exit signs within the Class 5 office areas are to be designed in accordance with Clauses E4.5, E4.6 and E4.8 from Volume One of the BCA and AS2293.1:2018.

0.5.4 Storage and Handling of Dangerous Goods

1. The client has not advised that any dangerous goods will be handled and situated within the development; and
2. Should the storage and handling of dangerous goods be proposed at any point in the future, this fire engineering documentation would be required to be re-assessed by a competent fire safety engineer.

0.5.5 Vehicular Access and Open Space Provisions

1. Perimeter vehicular access shall be provided in accordance with Clause C2.3 inter alia Clause C2.4, with the exception of the following:

a. The perimeter vehicular access is located more than 18m away from the external wall of the building (Warehouse A, B, C and D) due to the recess docks (i.e. up to 45m); and

b. Any perimeter fence gates (and gates forming part of the vehicular access) that are proposed to be locked are required to be fitted with suitable conventional padlocks to enable fire-fighter access with a standard key (i.e. 003 key locks). Alternatively, non-conventional padlocks are permitted provided access keys are provided to Fire & Rescue New South Wales (FRNSW) responding fire station stations.

0.5.6 Management in Use Requirements:

1. Maintain paths of travel to an egress, stair entrances, pedestrian doorways and thoroughfares free of static storage and combustible materials at all times; and
2. The client has advised that there shall be no dangerous goods stored within the warehouses; and
3. Smoking shall not be permitted within the building; and
4. All fire safety measures and Management in Use requirements shall be incorporated into an Essential Services list. All fire safety measures shall be maintained in accordance with the requirements of AS1851 (or equivalent maintenance standard) as identified by Scientific Fire Services. Management in Use requirements shall be inspected and logged on an annual basis; and
5. The recommendations forming part of the performance solution shall be identified as part of the Fire Safety Schedule for the subject premises and is to form part of the building's Essential Safety/Services List.

0.6 Brief Statement on Acceptability of Proposed Performance Solution

The basis of the following assessment, conditions, methodologies and acceptance criteria, the general and specific objectives, relevant hazards, preventative measures, the proposed trial design etc. are however, considered to be detailed within this report. The above requirements are not limiting. Schedules and records must be in accordance with AS1851-2012. There shall be evidence of all inspection whether maintenance was required or not. It is drawn to the client's attention that if this maintenance is not undertaken as per these instructions he may be fully liable to legal responsibilities and without the cover of insurance.

0.7 Fire & Rescue Comment to FEBQ Submission

Scientific Fire Services prepared the preceding Fire Engineering Brief (FEB) prior to this formal assessment being undertaken. The Fire Engineering Brief (FEB) (Ref. No.: 274221, Dated: 14/05/2021, Issue: 3.0) was issued to the design team, including the fire authority for comment. A Fire Engineering Brief Questionnaire (FEBQ) (FRNSW Project Ref: FRN20/887-1, FRNSW Job No.: BFS21/1563 v1-0, Dated: 14/05/2021, Version: 01)) was formally submitted to Fire and Rescue NSW (FRNSW) for formal comment.

Scientific Fire Services has consulted with all relevant stakeholders in relation to the general elements of the Fire Safety Engineering Report (FSER) and has documented the various elements of the FSER in accordance with agreements reached during the FEB and building design process.

It shall be noted that the FRNSW issued email correspondence communicating that FRNSW comment to the submitted FEBQ will not be provided. Refer to Appendix J for further details.

1. Introduction

1.1 General

This Fire Safety Engineering Report (FSER) has been prepared by Scientific Fire Services (SFS) for Hansen Yuncken Pty Ltd (NSW). The report details the fire safety engineering assessment that has been undertaken on the proposed design of Lot 202 (formerly referred to as Lot 204) Horsley Park.

The project is located at 10 Johnston Crescent, Horsley Park NSW and can be described as being comprised of the following BCA classifications.

Occupancy Use	BCA Classification
Warehouse	Class 7b (Storage)
Commercial office	Class 5 (Office)

The Building Solution proposed for this project, which is required to comply with the Performance Requirements of the National Construction Code 2019, Vol. 1, Building Code of Australia (BCA) (ABCB 2019), is a combination of Performance Solution and Deemed-to-Satisfy Solution elements in accordance with Clause A2.1 of the BCA.

Where requested, a Fire Engineering Brief (FEB) would be prepared. The FEB is the Performance-based Design Brief with specific reference to fire safety and is developed in collaboration with key stakeholders as part of the performance-based design and approval process.

A FEB, (SFS Ref: 274221 v3.0 dated 14/05/2021) was prepared for this project in accordance with the guidance of the International Fire Engineering Guidelines (IFEG)(ABCB 2005). This FSER includes the basis of the FEB and has taken into consideration relevant comments from the stakeholders.

An FEBQ (dated 14/05/2021) was prepared for this project in accordance with the FRNSW proforma and was subsequently submitted to the fire authority for its review and feedback.

The fire safety engineering assessment process, methodologies employed and reporting generally conform to the IFEG.

The FSER presents the analyses carried out to demonstrate compliance of the Building Solution with the Performance Requirements of the BCA.

1.2 Supporting Documentation

The assessment described in this report has been based on the referenced drawings prepared by HL Architects Pty Ltd. The drawings to which this assessment applies are listed in Appendix A.

The project issues, the proposed Building Solution and the intended assessment methodologies have been presented to and discussed with the relevant Fire Authority. Their comments and responses arising from these consultations are detailed in Appendix J

There are no other matters related to the Performance Solution and the proposed assessment methodologies that require Fire Authority consultation or approvals.

Documentation from the Building Certifier/Building Code Consultant identifying issues in regard to the proposed project design relevant to the fire safety engineering assessment are included in Appendix D.

1.3 Scope

1.3.1 Regulatory Framework

The National Construction Code is a uniform set of technical provisions for the design and construction of buildings and other structures and plumbing and drainage systems throughout Australia. It allows for variations in climate and geological or geographic conditions.

The BCA is given legal effect by building regulatory legislation in each State and Territory. This legislation consists of an Act of Parliament and subordinate legislation that empowers the regulation of certain aspects of buildings and structures and contains the administrative provisions necessary to give effect to the legislation.

Each State and Territory's legislation adopts the BCA subject to the variation or non-requirement of some of its provisions, or the addition of extra provisions. These provisions are contained in Appendices to the BCA.

Any provision of the BCA may be overridden by, or subject to, State or Territory legislation. The BCA must therefore be read in conjunction with that legislation.

In accordance with BCA Clause A2.1, compliance with the BCA is achieved by satisfying the Performance Requirements.

The *Performance Requirements* can only be satisfied by —

(1) A *Performance Solution*; or

(2) A *Deemed-to-Satisfy Solution*; or

(3) A combination of (1) and (2).

In accordance with BCA Clause A2.2, a Performance Solution must comply with the BCA.

(1) A *Performance Solution is achieved by demonstrating*—

(a) compliance with all relevant *Performance Requirements*; or

(b) the solution is at least *equivalent* to the *Deemed-to-Satisfy Provisions*.

(2) A *Performance Solution* must be shown to comply with the relevant *Performance Requirements* through one or a combination of the following *Assessment Methods:*

(a) Evidence to suitability in accordance with Part A5 of the NCC 2019 that shows that the use of a material, product, *plumbing* and *drainage product*, form of construction or design meets the relevant *Performance Requirement*.

(b) A *Verification Methods* including the following—

(i) The *Verification Methods* provide in the NCC; or

(ii) Other *Verification Methods* accepted by the *appropriate authority* that show compliance with the relevant *Performance Requirements*.

(c) *Expert Judgement*.

(d) Comparison with the *Deemed-to-Satisfy Provisions*.

(3) Where a *Performance Requirements* is satisfied entirely by a *Performance Solution*, in order to comply with (1) the following method must be used to determine the *Performance Requirement* or *Performance Requirements* relevant to the Performance Solution:

(a) Identify the relevant *Performance Requirements* from the Section or Part to which the *Performance Solution* applies.

(b) Identify *Performance Requirements* from other Sections or Parts that are relevant to any aspects of the *Performance Solution* proposed or that are affected by the application of the *Performance Solution*.

1.3.2 International Fire Engineering Guidelines

The IFEG document has been created for the purpose of providing guidance to experienced fire safety practitioners in the process and methodologies needed to demonstrate that a Performance Solution complies with the Performance Requirements.

IFEG is widely recognised as the appropriate document to be used as the basis of fire safety engineering assessments in Australia and other jurisdictions.

Since IFEG is a guideline document, the processes and methodologies adopted in an assessment may vary from those described in IFEG. However, any FEB and FSER documents prepared for a project should incorporate the essential information alluded to in IFEG.

1.3.3 General Objectives

The building regulatory objectives, though not explicitly stated in the BCA, are concerned with the issues of occupant life safety, fire services ability to perform their necessary tasks and protect adjoining properties. It is accepted that these objectives are satisfied by a Building Solution meeting the relevant Performance Requirements of the code.

The Fire Authority objectives are enshrined in State or Territory legislation. However, where appropriate, the Performance Requirements in BCA require consideration of fire brigade intervention in the assessment process. In undertaking the appropriate assessment of fire brigade intervention and showing compliance with the Performance Requirements, it can be taken that the objectives of the Fire Authority will be met.

SFS have not been advised of any additional regulatory objectives that are required to be considered during the assessment process for this project.

1.3.4 Client Objectives

The client has not identified any additional objectives for this project over and above those arising from the provisions of the BCA.

1.4 Stakeholders

The parties included in Table 1.1 have been identified as relevant stakeholders in this project.

The preparation of the FSER involves a consultative process. Input and collaboration has been sought from appropriate stakeholders as required.

Table 1.1: Project Stakeholders

Role	Company/Organisation	Representative
Client/Builder	Hansen Yuncken (NSW) Pty Ltd	Eng Khoon Tan Jerry Fanos David Fogg Metin Tokcan Owen Bersenev Elias Joya Jonathan Paparoulas Alyssa Webb
Architect	HL Architects Pty Ltd	Hong Lau
Building Certifier	McKenzie Group Consulting (NSW) Pty Ltd	Geoff Pearce Aaron Celarc
Fire Authority	Fire & Rescue NSW (FRNSW)	TBC
Fire Protection Services Engineer	Unified Fire Protection P/L	Evan Brown Naung Hann
Fire Protection Services Engineer	Sparks & Partners Pty Ltd	Leon Dimino
Mechanical Engineer	Grosvenor Engineering Group	Peter Souflias
Fire Safety Engineer	Scientific Fire Services	Parkan Behayeddin Kenny Leong

1.5 Role of Scientific Fire Services

IFEG recognizes that the fire engineering process may be considered to be used for two purposes, namely in the design of fire safety systems and components or, in the evaluation of a given fire safety system or systems. In the former case, experienced fire safety engineers may contribute to the project design process by assisting in the development and selection of effective and efficient fire safety systems. Once the design process has progressed to the point where a possible Building Solution has been developed, the fire safety engineer may then undertake the assessment of the proposed design in the manner prescribed by IFEG.

The above process is considered to be consistent with the 'application of the process' defined in the IFEG document.

In this project, Scientific Fire Services have not contributed to the detailed design development of the project in the preparation of the Building Solution offered for assessment.

1.6 Qualifying Statements

1. This FSER relates to the design detailed in the referenced drawings identified in Appendix A. These drawings have been relied upon to be an accurate representation of the project buildings. Any changes to the design aspects of the project for which a Performance Solution is supplied, subsequent to the issuance of this report must be referred to the Fire Safety Engineer for further assessment to ensure the continued compliance of the Building Solution with the Performance Requirements.
2. Scientific Fire Services has relied on the Building Certifier/BCA consultant to identify all the issues of non-compliance with the Deemed-to-Satisfy provisions of the BCA. Apart from these design issues listed in this report, it is taken that the proposed design meets all other Deemed-to-Satisfy provisions. It is also assumed that all other regulatory requirements have been met unless these have been specifically identified for assessment and inclusion in the FSER.
3. Where a building has previously included a Performance Solution it is presumed, unless specifically identified otherwise, that the prior Performance Solution has been appropriately approved.
4. Unless otherwise stated, the assessment does not address any issues that are outside the requirements of the BCA.

5. The outcomes of the assessment of the Building Solution stated in the FSER do not apply to any other parts of the building not included in the assessment, nor to any other building projects unless so identified by Scientific Fire Services.
6. The fire safety engineering assessment methodologies have been based on the assumption of a single ignition and fire source, which is the expectation of a natural fire start. The assessment does not consider multiple fire start scenarios arising from arson or other such events such as bushfire.
7. Analysis of emergency incidents such as bomb threats or other such occurrences, requiring partial or total evacuation of the building does not form part of this assessment.
8. The provisions for fire safety in this building, as incorporated into the Building Solution, have been assessed purely from the perspective of fire safety and their usage under any other circumstances is beyond the scope of this assessment.
9. Unless it has been specifically identified as an issue to be considered, this assessment does not include any consideration of losses arising directly or indirectly from a fire in respect of buildings, contents, business interruption, environmental damages or other consequential losses
10. The FSER and the subsequent recommendations are considered to reflect the reasonable and practical efforts of Scientific Fire Services. The extent to which the fire safety requirements are implemented will affect the probability of achieving adequate fire safety margins.
11. The outcomes of the fire safety assessment are conditional upon the required fire safety systems being installed, commissioned, operational and maintained as required by the relevant regulations, standards and specifications.
12. It is important to note, however, that there can be no guarantee that fire ignition and fire damage will not occur. No liability is accepted for any losses arising from a fire in this facility.
13. The assessment undertaken for this project is concerned only with the final completed and functional building. The assessment does not address any issues arising during construction, partial usage, renovation or demolition unless these aspects have been specifically identified for assessment.
14. The fire safety assessment undertaken is based entirely on the usage of the building/tenancy as described in the report. Any subsequent deviation from the usage as described will render this assessment invalid until a review by a qualified Fire Safety Engineer has been carried out.
15. Any occupant numbers used in the assessment have been derived in accordance with the provisions of BCA Clause D1.13 and, where appropriate, in collaboration with key stakeholders. Any increase in the occupant numbers above that designated in the report will render this assessment invalid until a review by a qualified Fire Safety Engineer has been carried out.
16. Any changes to the occupant characteristics, arising from such aspects as variations or changes to the building usage, to those designated in the report will render this assessment invalid until a review by a qualified Fire Safety Engineer has been carried out.
17. Issues associated with workplace Occupational Health and Safety have not been considered as part of this fire safety assessment.
18. This FSER has been prepared for the client identified in the report. The report is not transferable to another client without both the client identified in the report and SFS consent.
19. No liability is accepted for the accuracy of the documents and drawings supplied upon which this FSER is based.
20. Changes to the design, as shown in the drawings listed, subsequent to this report date will require fire safety engineering review to ensure ongoing compliance with the Performance Requirements.
21. Fires involving explosive components do not form part of this assessment.
22. The client has not advised that any dangerous goods will be handled and situated within the development; and
23. Should the storage and handling of dangerous goods be proposed at any point in the future, this fire engineering documentation would be required to be re-assessed by a competent fire safety engineer.
24. SFS has no role or responsibility in the use and management of the facility.

2. Building Description and Occupant Profiles

2.1 Building Description

The subject site is located at 10 Johnston Crescent, Horsley Park NSW whereby it is proposed to design and construct a Class 7b storage warehouse facility and associated Class 5 office/administration portions. The storage warehouse building is proposed to be sub-divided into four (4) tenancies as summarised below:

1. Warehouse A: 4,728m^2
2. Warehouse B: 2,454m^2
3. Warehouse C: 3,397m^2
4. Warehouse D: 3,156m^2

The building having a rise in storeys of not more than 2 (office portion) and a total floor area of approximately 16,513m^2. The building shall be treated as a *Large Isolated Building* and furthermore, shall be provided with automatic sprinkler protection throughout. Figure 2.2 illustrates the site layout.

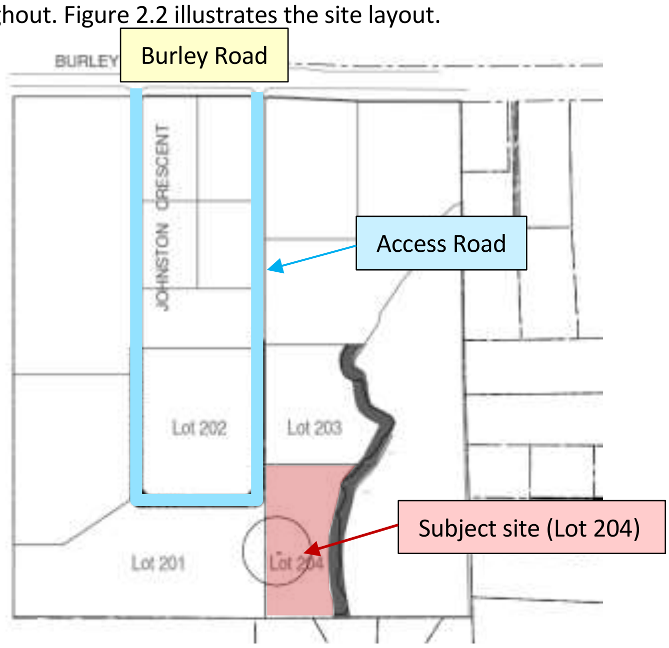


Figure 2.1: Key plan

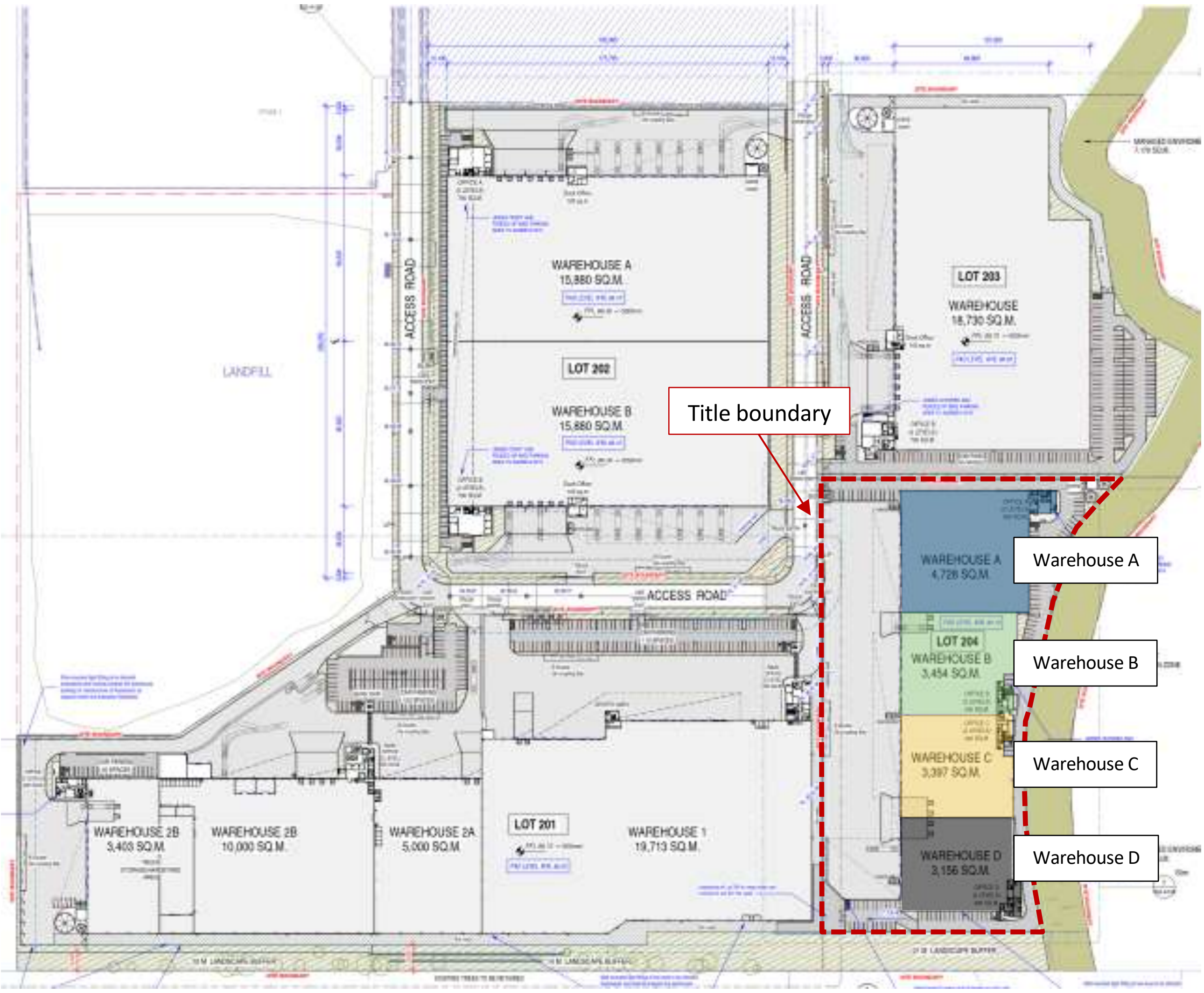


Figure 2.2: Site plan

Overall, the building shall comprise a rise in storeys of two (2) with a ridge height of up to 13.7m. As the volume of the proposed building exceeds the maximum volume limitation as permitted in Table C2.2 of Volume One of the NCC, the building has been classified as a 'Large Isolated Building' (LIB). The building is required by Clause C1.1 of the NCC to be constructed in accordance with Type C fire-resisting construction and shall be provided with an automatic sprinkler system incorporating storage sprinkler system in accordance with Clause E1.5 of Volume One of the NCC and AS2118.1:2017.

The building description based on the BCA classification system is provided in Table 2.1.

Table 2.1: BCA Description of the building(s)

Summary of Building/Tenancy	
Building Classification(s):	Class 5 (Office) & Class 7b (Warehouse)
Number of Storeys Contained:	Two (2)
Rise in Storeys:	Two (2)
Effective Height:	Ridge Height of up to 13.7m
Required Type of Construction:	Type C (Large Isolated Building)

2.2 Occupant Profiles

2.2.1 Occupant Characteristics

Understanding the likely nature of the building's occupants is an important element of the FEB. As with the building, there are many characteristics that can be identified making complete characterisation a complex and difficult task.

However, for the subject building development only a limited number of 'dominant characteristics' may affect the outcome, these are briefly described below.

Guidance provided by IFEG (2005); the Engineering Guide: Human Behaviour in Fire (SFPE 2003) and Proulx (2003) has been considered in the evaluation of dominant occupant characteristics for this fire safety engineering evaluation. Proulx gives the researched opinion that gender is having less effect on occupant response. Other researchers (Bryan 2003) suggest that females and aged residents are more likely to call for help. Men are more likely to attempt to extinguish the fire. Most occupants have a tendency to investigate (look for) the fire before deciding to evacuate.

The permanent occupant sub-group (staff) are anticipated as being of mixed gender and typically between the age of 18 & 60 years. The occupants are considered to be adequately mobile with no specific physical impairments that warrant attention with a more uniform level of physical and mental ability than other building classification. The staff members are considered to be familiar with the building environment in which they work and hence have an in depth understanding of the building layout and more specifically an understanding of the location of exits. It is expected that the staff would be trained in the building's emergency procedures and also in first attack firefighting with hose reels. It is noted that any transient occupant sub-group (i.e. visitors) would potentially comprise persons from all gender and age groups with varying levels of physical and mental ability. However, it is likely that visitors would be escorted and supervised while in the facility. This being said it is expected that there will be limited public contact within the warehouse portion of the building and as such these occupants are considered to be members of the staff.

2.2.2 Occupant Numbers

The client has advised that the occupant loading within the proposed building will be in the order of 660 occupants including future growth (refer to Appendix A.3) and as summarised below

- Warehouse A – 180 people
- Warehouse B – 160 people
- Warehouse C – 160 people
- Warehouse D – 160 people

2.3 Summary of Building Occupant Egress Strategy

The occupant egress strategy to be adopted for the subject development is such that when occupants are confronted with an emergency fire situation the building occupants make their way to a place of safety without being unduly exposed to the effects of fire, heat and smoke. Similarly, the occupants using the paths of travel to the numerous emergency fire exits are protected by the effects of fire during evacuations.

The proposed configuration of the subject building contains fire exits that are uniformly distributed along the facade of the building directly to the outside. The intent behind the egress provisions provided throughout the subject warehouse development is to enable occupants to identify logical and obvious escape routes which lead to places of safety. The large open nature of the subject building is reflective of this approach to safe occupant egress.

In the event of an emergency fire situation egress from within the proposed subject building is provided in the form of the following:

- Egress directly to the outside from the main warehouse portion of the subject building.
- Fire exits evenly distributed throughout the subject building.

2.4 Conditional Statement

It is not anticipated that the occupant characteristics or the usage of the building will change significantly. Any such change would require a re-assessment of the fire safety levels. The evaluation will consider the occupant characteristics identified and the usage of the building as noted. Any changes in the building usage and consequent potential change to the occupant characteristics will require a re-evaluation of the fire safety systems.

3. Performance Solution Design Issues

The Building Certifier/BCA Consultant has identified the following design aspects of this project that do not comply with the Deemed-to-Satisfy provisions of the BCA. For each of these issues an alternate Performance Solution has been presented and is the subject of the assessment herein to demonstrate compliance with the relevant Performance Requirements.

Table 3.1 lists the Performance Solution design issues to be addressed in the assessment, the applicable BCA DtS provision to which the Performance Solution applies, the Performance Requirement(s) to be satisfied and the Assessment Method to be adopted in accordance with Clause A2.2 of BCA.

Table 3.1: BCA design issues pertinent to the proposed Performance Solution

Design Issue to be Addressed	NCC DtS Provision	Performance Requirement
It has been identified that the super awnings located along the western portion of the building form part of the external wall and are located within close proximity to the title boundary (within 3.0m) without the required fire rating pursuant to Type C fire resisting construction. It should be noted that the super awnings contain openings that are located within 3.0m from the title boundary.	Clause C1.1 inter alia Specification C1.1 & Clause C3.2 inter alia Clause C3.4	CP1 & CP2
The following design issues have been identified with respect to the proposed perimeter vehicular access serving the building: • The perimeter vehicular access is located more than 18m away from the external wall of the building (Warehouse A, B, C and D) due to the recess docks (i.e. up to 45m); and • Any perimeter fence gates (and gates forming part of the vehicular access) that are proposed to be locked are required to be fitted with suitable conventional padlocks to enable fire-fighter access with a standard key (i.e. 003 key locks). Alternatively, non-conventional padlocks are permitted provided access keys are provided to Fire & Rescue New South Wales (FRNSW) responding fire station stations.	Clause C2.3 inter alia Clause C2.4	CP9
It has been identified that the exit travel distance to one of the alternative exits and distance between alternative exits within the <u>warehouse portion</u> exceeds the maximum prescribed exit travel distances. More specifically: **Warehouse A** • To permit the distance of travel to designated exits of up to 45m in lieu of 40m; and • To permit the distance of travel between alternative exits of up to 85m in lieu of 60m. **Warehouse B** • To permit the distance of travel between alternative exits of up to 66m in lieu of 60m. **Warehouse C** • To permit the distance of travel between alternative exits of up to 63m in lieu of 60m. **Warehouse D** • To permit the distance of travel between alternative exits of up to 63m in lieu of 60m.	Clause D1.4 Clause D1.5	DP4 & EP2.2
It has been identified that the exit travel distance to an exit within the <u>office portion</u> exceeds the maximum prescribed exit travel distances. More specifically: **Office A** • To permit the distance of travel to designated exits of up to 30m in lieu of 20m. **Office B** • To permit the distance of travel to designated exits of up to 30m in lieu of 20m. **Office C** • To permit the distance of travel to designated exits of up to 30m in lieu of 20m.	Clause D1.4	DP4 & EP2.2

Design Issue to be Addressed	NCC DtS Provision	Performance Requirement
The fire hydrant system shall be designed and installed in accordance with AS2419.1:2005 with the exception of the following: • Permit the fire hydrant booster assembly to not be within sight of the main entry of the building; and • Permit fire hydrants without the requirement for fire rated shield panels throughout the entire site; and • Permit fire hydrants to be located beneath awning structures and furthermore, be designed to achieve external fire hydrant performance; – In this instance, fallback fire hydrants will be required providing coverage to the fire hydrant located beneath the awning/canopy structure; and • Permit fire hydrants coverage to be calculated based on Clause 3.5.3.3(b) of AS2419.1:2017, where the building parts receiving coverage are within 70m of the external fire hydrants.	Clause E1.3 inter alia AS2419.1:2005	EP1.3
It is proposed to permit the sprinkler booster assembly and pump room is not be located adjacent to the principal vehicular entry, at the site boundary and not within direct line of sight of the main entry to the building.	Clause E1.5 inter alia AS2118.1-2017	EP1.4
It is proposed to omit the provision of an automatic smoke exhaust system within the building. In this instance, it is proposed to permit a manually operated smoke clearance system having a smoke clearance capacity of 1 air change per hour per warehouse enclosure.	Clause E2.2	EP2.2
Directional and non-directional exit signs are to be installed throughout the building in accordance with Part E4 from Volume One of the NCC and AS2293.1:2018 with the exception that the mounting heights of exit signage within the warehouse storage portions of the building. In this instance, it is proposed to permit exit signs to be mounted 5.5m above the finished floor level within the warehouse portion only in lieu of 2.7m as required by the prescriptive provisions from Volume One of the NCC.	Clause E4.8 inter alia AS2293.1:2018	EP4.2

4. Hazard Analysis

4.1 Introduction

The IFEG (2005) states that a systematic review should be conducted to establish potential fire hazards (both normal and special) of the facility under evaluation. A hazard is the outcome of a particular set of circumstances that has the potential to give rise to unwanted consequences. In regard to a building fire, a fire hazard means the danger in terms of potential harm and degree of exposure arising from the start and spread of fire and the smoke and gases that are thereby generated.

The fire related hazards in a facility can arise from the layout of the building including its location with respect to adjoining properties, the construction materials, the activities undertaken in the facility, the possible ignition sources and the fuel sources.

One of the first stages in reviewing potential fire hazards for a project is to examine available fire incident data for facilities having the same or very similar form and usage. This data may be international in origin and therefore must be used with care in order to establish possible hazards and a realistic measure of the possible unwanted consequences of fire.

Every hazard has a risk associated with it. The risk arising from a hazard is the frequency of an event involving that hazard, times, the expected consequences. A hazard may be eliminated, but there will always be an event frequency of occurrence and therefore always a positive value of risk associated with the hazard.

Fire safety engineering is essentially a risk management process wherein the outcome is to minimize the overall fire risk associated with a facility by mitigating or eliminating serious hazards, or by reducing the frequency of hazardous events.

The risk assessment process, of which hazard analysis forms part, is the means by which those hazardous events with the most serious consequences are identified. This then enables the most appropriate fire scenarios related to these events to be defined. This process then allows the analyses to be carried out to ensure that the fire safety systems and strategies employed are sufficient to satisfy the Performance Requirements.

Whilst the frequency of hazardous events (probability) is considered during the hazard analysis, the consequent analyses for the evaluation of the resultant fire scenarios are deterministic.

The following sections provide data specific to the occupancies involved in this assessment.

4.2 Summary of Project Specific Hazards

A thorough and comprehensive analysis of the fire hazards associated with the subject building has been provided in Appendix B of this FSER. A summary of the fire hazard analysis is provided in the following sub-sections presented below.

4.2.1 Summary of Hazards: Class 5 – Office

In relation to the office classification, the hazard analysis undertaken illustrates a number of consistent observations:

- While there is very little usable Australian fire statistics available, there are plenty of international sources of data (see Section C.1.2), and these overseas sources are relevant to the Australian built environment, so can be used with care to inform fire engineering and design in Australia.
- While it is largely impossible to define or regulate fire loads in office properties, most studies find a mean fuel load in the range of 300-700 MJ/m^2 (see Table C.1). Most of the fuel load in offices is in the form of paper or wood, but there are significant quantities of plastics and electronics present as well (see Table C.2).
- The ignition sources that produce the most frequent fires in offices are cooking equipment and, to a lesser extent, electrical equipment (see Figure C.7). This is even more the case for high-rise offices. The sources that produce the most fire-related property damage are arson and fires in adjacent properties.
- Statistics worldwide indicate that an office building rates relatively low with respect to the risk of fire when compared to buildings of other occupancies (see Section C.1.5).
- While (typically non-sprinkler-protected) mid- or low-rise offices are quite low risk, this is even more true of (typically sprinkler-protected) high-rise office properties (see Figure C.13).
- Offices are one of the occupancies with the lowest fire fatality risk (see Section C.1.6).
- Automatic sprinkler systems are very effective at reducing the severity of fires in office properties (Lougheed, 1997).
- Offices are an occupancy of low overall risk, and in particular have a significantly below-average risk to life.

4.2.2 Summary of Hazards: Class 7b – Storage

In relation to the storage classification, the hazard analysis undertaken illustrates a number of consistent observations. These observations are summarised below:

- While there is limited usable Australian fire statistics available, there are plenty of international sources of data (see Section C.2.2), and these overseas sources are relevant to the Australian built environment, so can be used with care to inform fire engineering and design in Australia. In storage occupancies in particular, this data leads to a number of observations:
- Fire loads in storage properties are extremely varied (see Table C.3), changing based on what product or material is being manufactured or processed, and also on the height of storage. Any fuel load for use in analysis will depend on the specific product and storage arrangements in question.
- The ignition sources that produce the most frequent fires in storage properties are arson, and mechanical and electrical failures (see Figure C.24). This is consistent with the overall lack of equipment or activity in storage occupancies, and indicates somewhat unique fire prevention needs.
- Statistics worldwide indicate that a storage building rates quite high with respect to the risk of fire when compared to buildings of other occupancies (see Section. C.25), and only residential buildings consistently display greater frequency of fires. Therefore, effective and efficient fire safety systems and practices are of additional importance for reducing this risk in storage properties.
- In conclusion, storage occupancies have a low risk to life due to fire. This is most likely due to the low number of occupants present in storage buildings, and due to the proportion of fires set by arsonists, who tend to target valuable property and take steps to avoid injury.

5. Approaches and Methods of Analysis

5.1 General

Consistent with the IFEG a quantitative deterministic absolute approach was adopted in the form of a 'timeline' analysis in order to measure the level of life safety achieved for the subject tenancies.

The alternative to a deterministic approach is probabilistic. This requires extensive statistical data. Adequate statistical data exists for a limited range of fire related issues and therefore a probabilistic analysis is invariably based on a comparative basis to a fully complying deemed to satisfy design equivalent building.

Given the complexity of the issues evaluated in this case and the existence of applicable and validated computational tools a quantitative analysis is deemed appropriate and necessary. When an evaluation is carried out on an absolute basis, the results of the analysis are matched against the objectives or performance requirements without comparison to deemed-to-satisfy or other 'benchmark' designs. This is the approach adopted in this evaluation.

5.2 Life Safety Analysis Methodology

The evaluation methodology relies on the construction of a timeline for the fire incident and occupant evacuation. With a timeline methodology, the approach has been based on the determination of the Required Safe Evacuation Time (RSET) for people to evacuate and the Available Safe Egress Time (ASET) for evacuation (before untenable conditions are present within the egress paths). The requirement for occupant safety is as follows and further illustrated in Figure 5.1.

Available Safe Egress Time (ASET) > Required Safe Egress Time (RSET)

Or

ASET > λ x RSET

Where,

RSET= $t_d + t_{dc} + t_t$

ASET= time of untenable conditions (t_u)

λ= Safety factor

And,

t_d*= time of fire detection*

t_r*= occupant response time*

t_{dc}*= pre-movement time*

t_t *= travel time*

t_u*= time for untenable conditions*

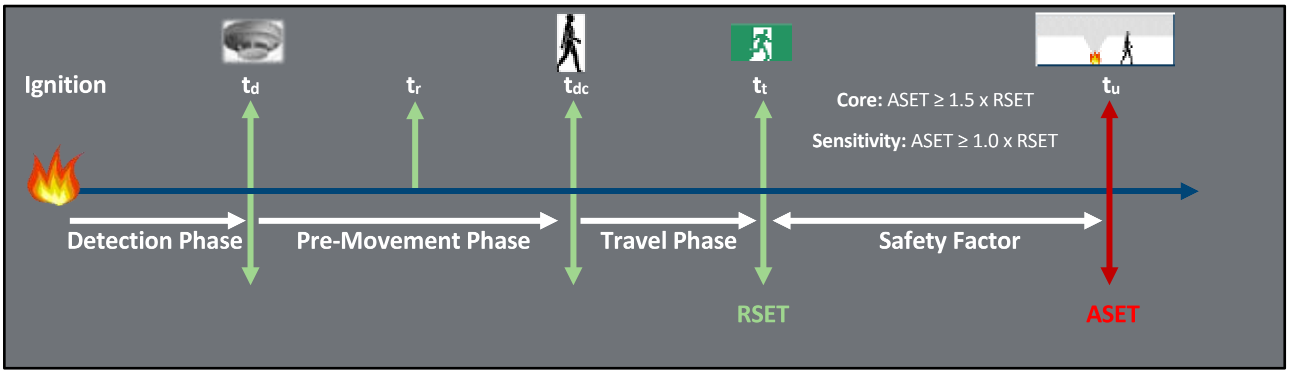


Figure 5.1: Schematic representation of the timeline analysis adopted

To undertake this analysis, the times for fire detection, occupant pre-movement, occupant travel and the time at which untenable conditions occur have been calculated. These times are calculated with the assistance of 'fire' and 'evacuation' models.

5.2.1 Performance Objectives

The project objectives are essentially to ensure that the performance solution is developed which demonstrates that the regulation Performance Requirements are satisfied and that the standard of fire safety is commensurate to that prescribed in Volume One of the BCA.

Elaboration of this core objective is provided in the following dot points:

- To satisfy the architectural vision and design specifications without compromising the code objectives.
- To preserve the functionality requirements of the open volume spaces for free circulation of occupants appropriate to the office/warehouse.

- To ensure a performance solution is developed which demonstrates that the code Performance Requirements are satisfied.

5.3 Method of Analysis

In order to address the identified, issue a quantitative analysis has been undertaken for the subject building project.

Quantitative analysis has been in the following forms:

- Computer simulation of fire development and smoke spread.
- Computer simulation of people movement.

5.4 Fire Modelling to Determine ASET

For the assessment of the subject development, the fire and smoke spread model Fire Dynamics Simulator (FDS Version 6.7.1) has been used to model the fire scenario. The NIST field model FDS is a Computational Fluid Dynamics (CFD) model of fire-driven fluid flow. The FDS software is appropriate for low-speed, thermally driven flow with the emphasis on smoke and heat transport from fires (K B McGratten et-al 2002). The FDS model used is a deterministic 'fire model' which is used to predict the spread of heat and smoke in an enclosure or multiple enclosures. Visual presentations of the FDS simulation modelling results are provided using the 'smokeview' program (K B McGratten et-al 2002).

CFD models, or as sometimes referred to, field models rely less on empirical correlations and are based on solving conservation equations for mass, momentum and energy. Fluid dynamics involves mathematical equations that describe the physical behaviour of fluids (gases and liquids) and are in the general form of three-dimensional, time-dependent, non-linear partial differential equations known as the 'Navier-Stokes' equations. The fire detection times are established by the time the automatic fire sprinkler system activates and/or by visual cues of smoke established in the FDS modelling undertaken. Further details of the Computational Fluid Dynamics model are presented in Appendix F.

5.5 Evacuation Modelling

5.5.1 Detection

The detection time has been based on determining the time at which the occupants in close vicinity of the fire see smoke from a developing fire and/or the time that the automatic fire sprinkler system operates within the facility. Not relying solely on the automatic fire sprinkler system and Building Occupant Warning System (BOWS) operating is considered to be conservative as a fire which is likely to have an impact on the building requiring evacuation is probably within the building itself and therefore detectable by the occupants well before automatic detection occurs. The BOWS will ensure that a building wide alarm is provided whereby any occupants located remote of the fire will receive warning to evacuate. The time at which the BOWS shall initiate has been calculated through the activation of sprinkler heads and utilising Alpert's Correlation.

According to studies conducted in 'Microeconomics Reform: Fire Regulation' (BRR 1991) at the time the smoke layer drops 5% from the ceiling height the occupants are expected to become aware of a fire via visual or olfactory cues. As such, it is considered that the smoke detection time for the building occupants will occur upon initiation of the BOWS or via visual cue. In the case of visual cue, fire detection has been based the descent of the smoke layer from ceiling level. For conservatism, the time of visual fire detection is based on the time taken for the smoke layer to drop 10% from the ceiling height due to the fire being located in a large enclosure.

5.5.2 Pre-Movement

The pre-movement component of the evacuation process often has the greatest variability and hence is often the largest time part in the total evacuation process.

This is as a result of human behaviour and more specifically the variance in how people react/cope in certain situations. Furthermore, the warehouse is quite big in size, whereby a fire may ignite in one section may or may not be seen in the adjacent portion due to racking, pallets and vehicle loading and unloading. Various fire safety or fire protection engineering related publications identify appropriate pre-movement times for warehouse type occupancies with automatic detection and warning systems. Among these publications are The British CIBSE (Chartered Institution of Building Services Engineers) Fire Engineering Guide E (CIBSE, 2010) and Society of Fire Protection Engineering Handbook (SFPE, 2008).

Most publications rely on BS7974-2001 "Application of fire safety engineering principles to the design of buildings – Code of practice" in identifying pre-movement times for different classifications of buildings with varied detection and warning systems and emergency evacuation procedures. Studies by prominent fire behaviour researchers (i.e. Proulx, Fahey, Brennan) have observed that perceived threat would reduce the response and pre-movement times. The presence of smoke or flames results in increased levels of threat for occupants. This concept has been relied upon in the development of a risk contour-based methodology which was presented in the Human Behaviour in Fires Conference in

2009 and later published as part of the proceedings (Horasan, Kilmartin 2009). The concept may be summarised as follows:

- In small buildings pre-movement times, may be relatively short as the perceived threat of the fire is real and as such the occupants identify the risk whereby a decision to intervene or evacuate would be expected to follow intuitively. Furthermore, applying a standard pre-movement time for the evacuating occupants to larger buildings may result in oversimplification of the evacuation process leading to inappropriate estimations either too speculative or overly conservative.
- The pre-movement time in this instance has been determined based on statistical data, literature review and the visual cue of a fire. Therefore, it is considered appropriate that any occupants located within the direct vicinity of the fire will become aware of a fire and will start their movement phase more rapidly hence it is expected that these occupants would have a reduced pre-movement time. Similarly, occupants located remote from the fire will take considerably longer to decide on an appropriate course of action as a result of the fire not being a direct threat hence occupants further away from the fire will have an increased pre-movement phase. This phenomenon has been considered in the occupant evacuation analysis undertaken.
- Where a fire is assumed to occur the immediate adjacent areas to the fire have been assumed to have a corresponding risk IR1 which the expected risk is assumed to be greater than all other areas within the building. Risk contours provide a visual indication of individual risk at any point. It is noted that the literature suggests that reasonable and conservative judgement for contour boundaries must be incorporated in the assessment. Therefore, the surrounding areas of the fire origin (IR1) would have a relatively lower level of risk at IR2. Further away from the origin of fire the risk values, i.e. IR3, IR4 and IR_n, are further reduced.

Table 5.1 is reproduced from the 4th International Symposium on Human Behaviour in Fire and details a qualitative summary of the expected risk phase.

Table 5.1: Contour risk phase (Table 1, 4th International Symposium on Human Behaviour in Fire, 2009)

Zone	Detection and response r_t	Delay d_t	Movement m_t	Magnitude comparison
IR1	Quick occupant response based on visual detection most likely prior to any automatic warning system activation.	Very short delay time due to abundance of cues and high perception of threat.	Movement speed a function of perceived threat, short movement time to the nearest safe area.	R_{t1} d_{t1} m_{t1}
IR2	Quick occupant response based on visual and/or automatic detection.	Longer delay time due to lower perception of threat.	Movement time a function of occupant numbers, exit widths and exit distribution.	$R_{t1}<r_{t2}$ $d_{t1}<d_{t2}$ $m_{t1}<m_{t2}$
IR3	Longer response time due to detection based on warning systems and absence or insignificance of visual cues.	Longer delay time due to even lower perception of threat.	Movement time a function of occupant numbers, exit widths and exit distribution.	$R_{t2}<r_{t3}$ $d_{t2}<d_{t3}$ m_{t3}^*
Irn	Longer response time due to detection based on warning systems and absence or insignificance of visual cues.	Longer delay time due to even lower perception or total absence of threat.	Movement time a function of occupant numbers, exit widths and exit distribution.	$R_{tn-1}<r_{tn}$ $d_{tn-1}<d_{tn}$ m_{tn}^*

An indicative illustration is provided in Figure 5.2, highlighting the potential contoured pre-movement approach relative to the area of fire origin (AFO).

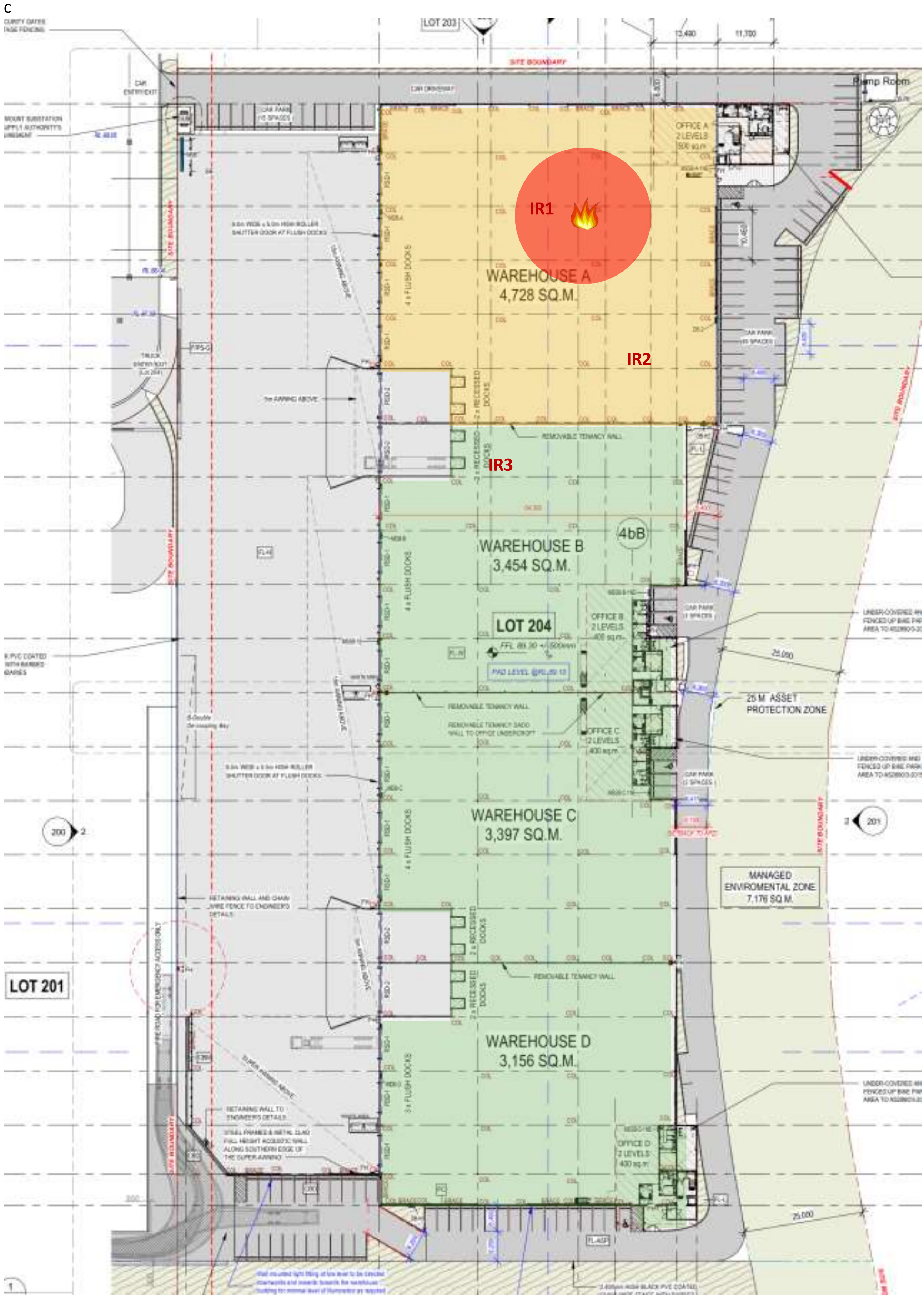


Figure 5.2: Indicative schematic pre-movement contour summary

This concept has also been adopted and reflected by the New Zealand Department of Building and Housing as part of the Building Codes in the document titled "C/VM2 Verification Method: Framework for Fire Safety Design For New Zealand Building Code Clauses C1-C6 Protection from Fire". The C/VM2 document recommends a sliding scale of pre-movement times based on an occupant's location with respect to the fire origin.

Occupancies such as the subject warehouse are highly appropriate for adopting the risk contours approach. Visual access to other sections of the building is not always assured. Hence, in the event of a fire in one particular portion, the occupants within the immediate vicinity would become aware of the fire immediately while occupants located in other portions would rely on secondary warnings such as alarms, staff or other occupants moving away from the zone of fire origin.

The pre-movement time would incrementally increase for zones further away from a fire when located in the different operational sections of the warehouse or area of AFO. In the context of the AFO, the risk contour shall be divided into intervals and other remote zones based on the location of the fire and the position of storage racking arrangements and the like within the warehouse. The zone of fire origin is identified as IR1 (i.e. the highest perceived risk) and allocated the shortest pre-movement times.

5.5.3 Movement

The subject building is defined for evacuation modelling purposes in the form of the floor plans constructed which have been used as the templates for the computer modelling software Pathfinder.

Occupant movement modelling have been conducted using Pathfinder, which determines the occupant travel times appropriate to the fire scenarios modelled. This software is based on real human behaviour, using data gathered from video analysis of individuals moving in crowds. The models are a PC-based program capable of simulating the evacuation of large numbers of people through geometrically complex buildings. Further details of the 3D Human Movement Simulation modelling are provided in Appendix G.

The travel time during an evacuation process is governed by the movement speed of occupants or queuing at potential bottlenecks such as at a fire-isolated stair. As a conservative approach travel distance is considered to govern the movement speed which would not necessarily be the case where maximum occupant loading is present within an enclosure.

Travel time of an occupant to a place of safety is generally the most predictable and typically is the smallest time involved. Travel speeds recommended by the SFPE Handbook of Fire Protection Engineering (5th Edition, 2017) for a corridor or an aisle is 1.19 m/s. For persons with limited mobility, i.e. a person on crutches, travel speeds as high as 0.94m/s are recommended (Ramachandran & Charters, Quantitative Risk Assessment in Fire Safety, 2011). This correlates well with studies conducted by various researchers detailed in 'Egress Design Solutions' (Lord et al, 2005 & Fahy et al 2001) and Kuligowski (2005) which have established occupant walking speeds for different occupant groups and/or disability and the corresponding travel speeds are provided in Table 5.2.

Table 5.2: Horizontal walking speeds for varying occupant groups (Egress Design Solutions, 2007 and Kuligowski, 2005).

Occupant Group	Walking Speed	Comments
Children (0-6 years old)	0.4 m/s	Not applicable
Children (7-12 years old)	0.8m/s	Not applicable
Male (13-69 years old)	1.2 m/s	Present within the warehouse portions
Female (13-69 years old)	1.0 m/s	Present within the warehouse portions
70+ years old	0.8 m/s	May be present within both office and warehouse portions.
Mobility impaired	0.5 m/s	May be present within both office and warehouse portions.
Average	**0.87m/s**	Calculated average occupant movements speeds within the warehouse portions.

The travel time component of the evacuation process in this class of building is generally based on a determination of the time for occupants to move to a place of safety. For the subject building, occupants located within the warehouse portions of the building are expected to be able bodied occupants whom are trained to be able to manually handle stored goods and commodities within the building. Furthermore, the facility will rely on occupants to be abled bodied whom are licenced to operate vehicles including forklifts and also be in a position to be able to move stored goods either mechanically or manually. It is noted that in the office portion of the building physically impaired occupants may be expected. However, in this instance the egress provisions within the office portion are understood to comply with the prescriptive provisions from Volume One of the BCA.

Based on the likely characteristics of the occupants, the geometry of the building and the proposed egress provisions, the occupants would be expected to traverse at their normal walking speed to the subject exit locations (Lord et al, 2005 &

Fahy et al 2001). This is a result of a limited number of occupants present at any given time. The occupants located within the warehouse portions of the building are also expected to be alert at the time of the emergency fire situation and furthermore, trained in emergency evacuation procedures.

The occupant movement analysis has adopted an occupant movement speed of **0.8m/s**. According to the above literature the movement speed of **0.8m/s** is considered conservative when considering the average movement speeds for walking and ignoring the fact that the majority of these occupants would be moving in an emergency situation. Regardless of the marginal differences in speeds by adopting the relatively slower 0.8m/s movement speed, the proposed building design is likely to be further accommodated for in the applied safety factors (as detailed below) for the combined design scenarios.

5.5.4 Factors of Safety and Redundancies Summary

A factor of safety has been applied during or at the end of the numerical analysis in order to ensure sufficient levels of conservatism are introduced to the analysis and all uncertainties are compensated for. The magnitude of the factor used depends on:

- The reliability of the various components of the fire safety system.
- The results of an uncertainty analysis.
- The criteria used to determine acceptance.
- For example, for the ASET/RSET assessment for occupant life safety the factor of safety adopted is in excess of 1.5. In other words, the following criteria has been met:

  ASET > 1.5 x RSET

- For the ASET/RSET assessment for fire services personnel safety the factor of safety adopted is in excess of 1.5. In other words, the following criteria has been met:

  ASET > 1.5 x FBIM (commencement of water application)

- Redundancy and factors of safety are two concepts that are considered concurrently. The redundancies in the design are considered in this analysis in order to ensure levels of conservatism. Factors of safety adopted for sensitivity studies scenarios are adopted have been reduced to 1. Therefore:

  ASET > 1.0 x RSET

5.6 Adopted Tenability Criteria

5.6.1 Building Occupant Tenability Criteria

The tenability criteria for occupant life safety is based on information obtained via the SFPE Handbook and various other publications in relation to occupant tenability limits. These documents state that for occupant life safety the environmental conditions must be maintained so that excessive temperatures, low levels of visibility and high levels of toxicity do not endanger human life. Based on this approach, two distinct tenability criteria have been set out in relation to occupant life safety.

5.6.1.1 Primary Criteria: Occupants not exposed to the hot smoke layer

Condition: *The smoke layer <u>must remain above</u> a certain level from the floor*.

A smoke layer height commonly adopted universally in relation to tenability is 2 metres from the floor. This criterion is taken into consideration in conjunction with the radiant heat from the hot smoke layer. The radiant heat is required not to exceed 2.5kW/m^2, at head height. This equates to a temperature of approximate 183°C and an average human height of 1.9m. However, to add conservatism into the design the maximum allowable temperature is commonly increased to 200°C at a height above the floor level of 2m.

It should be noted that, while with zone models it is possible to demonstrate the hot smoke layer height clearly with relative ease, when CFD models are used a clear stratification is not expected to be demonstrated in the output. However, slices at 2m above floor levels are provided for guidance. It is further noted that the secondary criteria listed above relates to smoke conditions where the smoke has descended to levels below the primary criteria of 2m smoke layer height.

The criteria of temperature and smoke visibility are only applicable should the smoke layer interface drop below 2m.

5.6.1.2 Secondary Criteria: Occupants exposed to the hot smoke layer

Condition: *The smoke layer <u>may descend below</u> a certain level from the floor, but the conditions must remain "tenable"*.

If the hot smoke layer descends below the layer height adopted in relation to Criteria One and occupants are exposed to the hot smoke layer a secondary set of criteria is taken into consideration in relation to tenability which include:

- Convective heat; and
- Visibility; and

- Toxicity

It is should be noted that the secondary criteria relate to smoke conditions where the smoke has descended to levels below the primary criteria of 2m smoke layer height. The criteria of convective heat, smoke visibility and toxicity are only applicable should the smoke layer interface drop below 2m.

Convective Heat

In relation to convective heat the objective is to limit the temperature to allow occupants to evacuate without being incapacitated due to burns or hyperthermia.

According to the SFPE handbook an acceptable temperature threshold for heat to not irritate or burn humans is taken as 60°C. However, this being said the skin and lung track can endure higher temperatures for extremely short periods of time up until the temperature reaches approximately 100°C at which time the effects of the convective heat may cause burns and/or hyperthermia in humans. Nevertheless, to be conservative an acceptance criterion of 60°C within the hot smoke layer when the hot smoke layer drops below 2m was adopted.

Visibility

Reduction in visibility by smoke does not directly cause incapacitation of human bodies. However, poor visibility may hinder or prevent evacuation activities. Jin (1997) has shown that persons will move through smoke down to visibility of about 4m when in familiar surroundings and through smoke with a visibility of about 13m when in unfamiliar surroundings.

It can be expected that the predominant numbers of occupants egressing under fire evacuation conditions will be familiar with the building. However, there are relatively long travel distances for the occupants of some buildings to reach the stairs and/or exits and under these circumstances it is considered that a visibility of less than 10 m may cause concern to the occupants to the extent that egress may be avoided. This visibility requirement relates to an optical density of the smoke layer of $0.1m^{-1}$.

Consequently, the criteria for tenability based on visibility will be that the optical density of the smoke layer below 2m does not exceed $0.1m^{-1}$. For small enclosures, the visibility limit is set at 5 metres which equates to an Optical Density of approximately $0.2m^{-1}$.

Activation of sprinkler or other suppression systems has effects on smoke layer formation and visibility. However, research on quantifying these effects has not been reported in the literature. Since the effect of visibility on tenability is secondary, its reduction due to sprinkler spray is not regarded as a life safety criterion if it can be shown that the fire will be extinguished before excessive temperatures or toxic conditions are reached (FCRC, 1996).

Toxicity

It is now well recognised that exposure to toxic smoke products is one of the principal causes of death in fires (Purser, 1995). The parameters of toxicity are mainly dosage related. The time of exposure to any toxic gases and the intensity at which they are experienced are integrated to assess the impact of the exposure. There is now also recognition that the narcosis inducing effects of toxic gases are not independent but additive.

The most common toxic gas found in hot smoke layers is CO and research studies show that incapacitation due to CO occurs prior to incapacitation due to other toxic gases. SFPE Handbook of Fire Protection Engineering (2016) which provides tenability limits for common asphyxiant products of combustion. The concentration for incapacitation for each 5 minute or 30-minute period of exposure would result in a tenability limit of 30,000-42,000ppm.min respectively.

Table 63.28 Tenability limits for incapacitation or death from exposures to common asphyxiant products of combustion

	5 min		30 min	
	Incapacitation	Death	Incapacitation	Death
CO	6000–8000 ppm	12,000–16,000 ppm	1400–1700 ppm	2500–4000 ppm [65, 105]
HCN	150–200 ppm	250–400 ppm	90–120 ppm	170–230 ppm [65, 80]
Low O_2	10–13 %	<5 %	<12 %	6–7 % [33, 37, 65]
CO_2	7–8 %	>10 %	6–7 %	>9 % [33, 37, 65]

NFPA 130 provides tenability criteria for Carbon Monoxide levels for a range of threshold values. The allowable CO concentration (ppm) for different time intervals is summarized in the table below (2013 [9]).

Time (min)	Tenability Limit AEGL2	0.3	0.5
4	-	1700	2844
6	-	1138	1896
10	420	683	1138
15	-	455	758
30	150	228	379
60	83	114	190
240	33	28	47

Table 4. Various Tenability Criteria for Exposure to Carbon Monoxide

Figure 5.3: Tenability Limits (Left - SFPE Handbook of Fire Protection Engineering (2016) & Right - NFPA 130 values)

Based on the above references, CO ranges anywhere between 4,000 – 9,000ppm.m., for the purpose of the fire modelling analysis and tenability conditions a CO mid-range value of 6,800ppm.min has been used, which is representative of the NFPA 130 data (based on a concentration of 1706 ppm for an exposure period of 4 minutes).

Unless the fire is one in which the nature of the materials being burnt produces excessive amounts of carbon monoxide or other toxic products, then the CO exposure and other toxicity exposure time limits are usually much longer than the exposure times for occupants evacuating through smoke in typical buildings. In other words, for alert and awake occupants evacuating a building, incapacitation due to toxicity is not a common occurrence. The following table provides a summary of tenability criteria discussed above.

Table 5.3: Occupant Tenability Limits

Factor	Criteria
Primary Criteria	
Smoke Layer Height	> 2.1 metres
and	
Radiant Heat Flux Received by Occupants	< 2.5kW/m^2 (smoke layer temperature <200° C)
Secondary Criteria	
Smoke Layer Height	< 2.1 metres
and	
Smoke Temperature	< 60° C
and	
Visibility	> 10 m
and	
CO exposure dose	6,800ppm.min

5.6.2 Fire fighter Tenability Criteria

The acceptance criteria for fire-fighter life safety is based on the information obtained from AFAC's Fire Brigade Intervention Model (FBIM) in relation to tenability limits.

Fire fighters undertaking fire-fighting activities do not have the equivalent tenability criteria as would the occupants within the building (Refer to Table 5.3 occupant tenability criteria and Table 5.4 fire fighter tenability criteria).

The AFAC's FBIM states the acceptable criteria in that fire-fighters should be able withstand a far greater radiant heat flux, temperature and work at a hot smoke layer height much less than that of the evacuating occupants. This is so, as fire-fighters are dressed in fire protective clothing and provided with breathing apparatus (i.e. standard A26 tunics with over trousers to an equivalent specification, fire hoods, gloves, helmets, and rubber boots). Therefore, a summary of the fire brigade tenability limits applicable to the subsequent fire safety engineering analysis of the subject building is provided in Table 5.4. This information is originally obtained from a paper written in the Fire Journal, January 1995. The project has been carried out by the UK Home Office Fire Experimental Unit.

Table 5.4: Fire brigade Tenability Limits

Factor	Criteria
***Routine Condition** – Elevated temperatures, but not direct thermal radiation*	
Maximum Time	25 minutes
Maximum Air Temperature	100°C (in lower layer)
Maximum Radiation	1 kW/m^2
***Hazardous Condition** – Where, fire-fighters would be expected to operate for a short period of time in high temperatures in combination with direct thermal radiation.*	
Maximum Time	10 minutes
Maximum Air Temperature	120°C (in lower layer)
Maximum Radiation	3 kW/m^2
***Extreme Condition** – These conditions would be encountered in a snatch rescue situation or a retreat from a flashover.*	
Maximum Time	1 minute
Maximum Air Temperature	<160°C (in lower layer) & <280°C (in upper layer)
Maximum Radiation	<4kW/m^2
***Critical Conditions** – Fire-fighters would not be expected to operate in these conditions, but could be encountered. Considered to be life threatening.*	

Factor	Criteria
Maximum Time	<1 minute
Maximum Air Temperature	>235°C (in lower layer)
Maximum Radiation	>10 kW/m^2

*** Note:** All conditions (such as air temperature, visibility, humidity, incident thermal radiation, air flow past the fire-fighter, and time for which they are exposed) are relative to a height of 1.5m above floor level. The acceptance criteria has achieved routine conditions for all of the fire scenarios undertaken.

6. Fire Brigade Intervention

6.1 General

Fire Brigade tenability was analysed and compared in terms of temperature and fire-fighter exposure limits. The Fire Brigade Intervention timeline has been estimated and assessed whereby Fire Brigade Intervention and/or fire-fighting operations is listed as sub-requirements of the relevant Performance Requirements of the BCA.

Fire brigade intervention is required to be analysed to determine the potential impact on the activities of the fire brigade. This relates primarily to the impact of potentially fire spread of the building elements or structure coupled with occupant and fire-fighter tenability limits with respect to the time required for fire brigade personnel to arrive and undertaken search, rescue and extinguishment activities. For the purpose of determining a time at which the local fire brigade would attend a potential fire located at the subject building, a Fire Brigade Intervention Model (FBIM) (AFAC, 2020) has been undertaken.

The approximate Fire Brigade arrival time for intervention activities has been estimated and assessed whereby Fire Brigade arrival and/or fire-fighting operations is listed as sub-requirements of the relevant Performance Requirements of the BCA. The subject site is within the Fire Rescue New South Wales (FRNSW) jurisdictional area.

The nearest primary responding fire stations to the subject site via road travel have been illustrated in Figure I.1. The relevant fire stations are as follows:

- Huntingwood Fire Station located at 42 Huntingwood Dr, Huntingwood, NSW (approximately 9.1km away); and
- Bonnyrigg Heights Fire Station located at 70 Gloucester St, Bonnyrigg Heights, NSW (approximately 14.6km away).

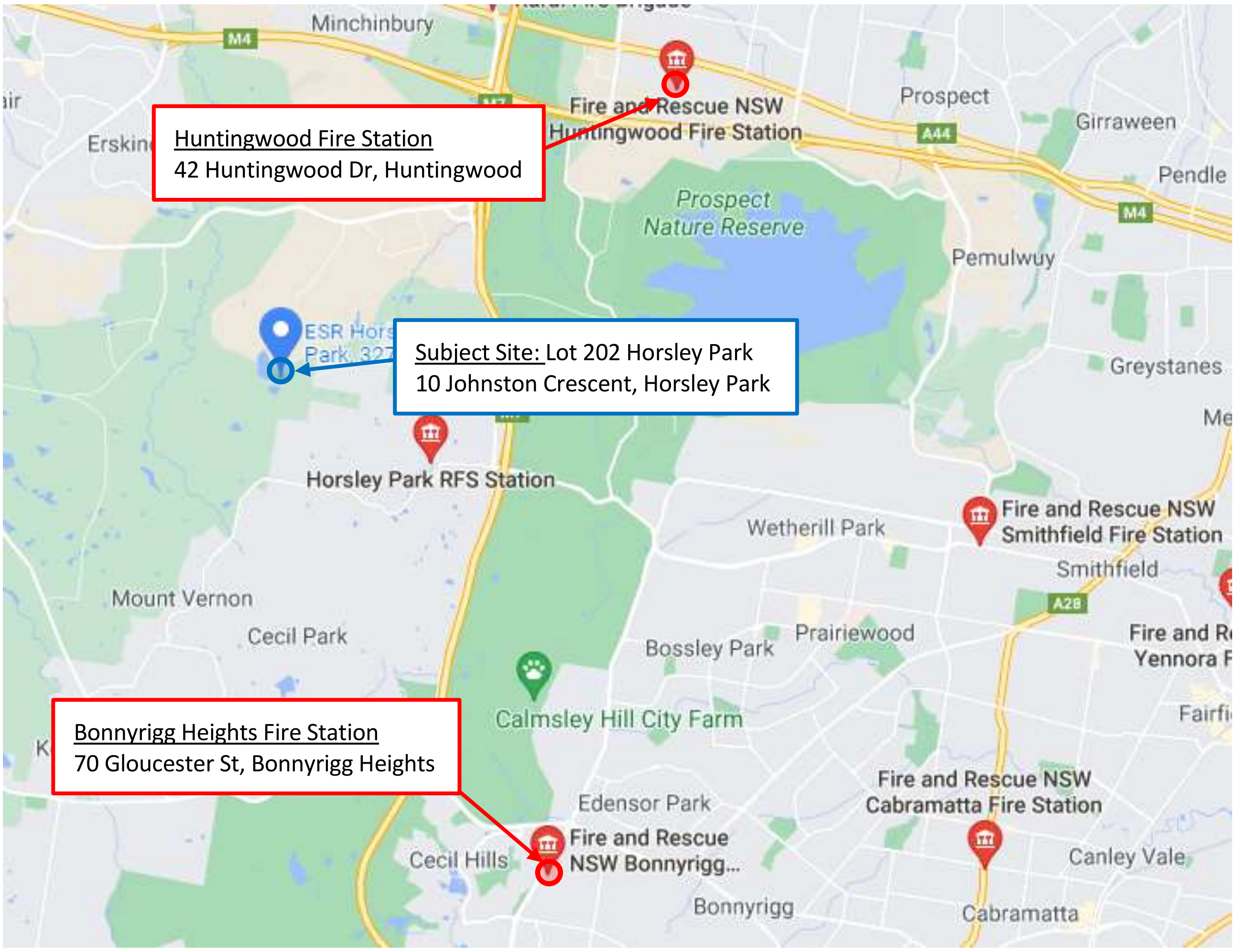


Figure 6.1: Primary responding FRNSW fire stations (Huntingwood & Bonnyrigg Heights) to 202 Horsley Park

6.2 Assumptions and Parameters

In this instance, a FBIM was undertaken from notification to commencement of water application at the most remote location of the building. The following assumptions and parameters were also adopted to determine Fire Brigade Intervention:

- Google Maps TM has been used to identify the most appropriate travel time from the station to the subject site.
- Based on information provided by FRNSW, both the nominated fire stations are permanently staffed;
  - As the fire stations are fully manned, the FBIM timeline has adopted an additional 90 seconds to account for firefighter response with respect to “Time to dress, assimilate information and depart”;
- Fire fighters including the Officer in Charge (OIC) would be required time to don BA gear and gather necessary information.
- Detection is based on Sprinkler activation
  - The sprinkler activation times were determined using Alpert’s Correlation. The spread sheet model has computed the thermal response of a sprinkler head located near the roof. The formulas are calculated with reference to R.L. Alpert Fire Technology 1972 pp181-195.
  - The activation of the automatic fire sprinkler system is expected to occur at 218 seconds.
  - The sprinkler activation time is based on Fire Scenario HP01C_8.6WA
- Assume fire-fighters travel to the subject site and set up in the most practical area for the fire brigade appliances. The fire brigade are assumed to set up at the main entrance location in front of the building to assess the location of the fire.
- The attending crew would be expected to receive information about the location of the fire via the main Fire Indicator Panel (FIP) if it was not visible upon arrival.
- As the occupants are expected to be evacuated and/or in the process of evacuation from the building forced entry is not expected.
- Fire crews deploying Standard Operational Guidelines (SOG’s) and equipped with fire-fighting tools and protective clothing are unlikely to be at exposed to excessive fuel loads, ignition sources and extra ordinary hazards within the subject building when compared to a building solution compliant with the DtS provisions of the BCA.

6.3 Fire Brigade Intervention Analysis Outcome

The activities performed by the attending fire crews, the time associated per activity and the cumulative time from fire initiation until the commencement of water application onto the fire is tabulated in Table I.5. The FBIM timeline indicates the following:

- From fire initiation the cumulative time taken for the closest & second closest fire appliances to reach the fire scene (kerb side) are as follows:
  - Closest (Huntingwood Fire Station): **1708 seconds** or approximately 28.5 minutes;
  - Second Closest (Bonnyrigg Heights Fire Station): **1888 seconds** or approximately 31.5 minutes;
- Having arrived at the fire scene (kerb side), the cumulative time taken for fire crews to gain entry, gather information, assess the situation and set-up water supplies ready for the commencement of water control/extinguishment activities is an additional **641 seconds** or approximately 10.5 minutes;
- From fire initiation to the commencement of water control/extinguishment activities the cumulative time take for the closest & second closest responding fire stations is as follows:
  - Closest (Huntingwood Fire Station): **2349 seconds** or approximately 39 minutes;
  - Second Closest (Bonnyrigg Heights Fire Station): **2529 seconds** or approximately 42 minutes

In line with the AFAC FBIM Model Manuel (Version 3.0, dated 14/04/2020) the total time taken for fire brigade intervention is based upon the second closest fire station. In this regard, attending fire crews from Bonnyrigg Heights Fire Station are expected to conduct water control/extinguishment activities within **2529 seconds** or approximately 42 minutes.

7. Life Safety Analysis – Design Fires and Evacuation Scenarios

7.1 Fire Scenarios

To evaluate the performance design in terms of occupant and fire-fighter safety a number of fire scenarios have been considered. These fire scenarios examine the sequence of events from fire ignition to fire detection, occupant response and egress, fire suppression and development of untenable conditions within the egress paths.

The modelled fire scenarios will take account of factors, such as:

- Ignition sources.
- The nature, quantity, arrangement and burning behaviour of combustibles in each enclosure.
- Enclosure geometry.
- Number of enclosures and their relationship.
- Connections between enclosures.
- The fire protection measures in the building and their effect on the fire.

Time periods have been quantified for each fire scenario are detailed in the following sub sections:

7.1.1 Primary Events

- Time of fire detection
- Occupant pre-movement time
- Occupant travel time
- Time of untenable conditions

7.1.2 Secondary Events

- Suppression system activation time
- Smoke control system activation time
- Fire brigade intervention time

The number of possible fire scenarios in the proposed building can be very large and often there is insufficient data and resources to quantify them all. Therefore, detailed analysis and quantification is often limited to the most significant fire scenarios. The fire scenario detailed in the following sub-sections has been developed for the purposes of input into the timeline analysis. In addition, the core design fire scenario has been used as input for the purposes of smoke and evacuation modelling.

7.2 Credible Fire Scenarios

Although the development of the design fires typically involves quantification of the worst credible fire scenario, other scenarios may need to be considered for the purposes of sensitivity analysis.

Therefore, it is considered that the content and purpose of the warehouse is known whereby a high percentage of the expected commodity is stored in plastic and/or cardboard boxes and the like, stacked in racking and on pallets.

The subject buildings are expected to store/transfer items/goods in a very similar manner to a typical storage warehouse with forklifts, manual pallet jacks, aerial work platforms and the like being utilised within the buildings. In this regard, it has been identified that the proposed use of the warehouse is for storage and distribution of goods. Any change from this will require a reassessment.

Based on the aforementioned design advice, the buildings are expected to have high racking and particular areas within the floor with double stacked pallets. To assist in the functionality of the buildings high level electrical lighting shall also be afforded for the building occupants. Therefore, as part of the operation within the warehouse electrical and mechanical equipment such as forklifts, pallet jacks and the like may be utilised to shift stock prior to loading or unloading delivery vehicles. It is noted that the mechanical lifting equipment used internally to shift storage is expected to be battery powered.

Given the simple geometric shape of the warehouses the location of the fire for modelling purposes is not considered critical unless it is located too close to the walls and there is a boundary effect on the plume. Within the warehouses a fire can be expected to ignite in any one place at any one time. Whilst the proposed location of the fire may not be considered to be the greatest area of fire risk and is possibly an unlikely source of a major fire in conjunction with a maximum population present within the warehouse, it is used as it consists of fuel loads orientated vertically (within a racking system and pallet areas) thus the likelihood of rapid-fire spread is expected to be increased.

Although the development of the design fire typically involves quantification of the worst credible fire scenarios. The fire scenarios for the proposed development adopted in this FSER are detailed in Table 7.1 and illustrated in Figure 7.1. The naming convention of fire scenarios are described below:

Fire Scenario ID: **HP01C_8.6WA**

- Project name: Horsley Park
- Scenario number: 01, 02, etc
- Type of scenario: C = Core scenario, S = Sensitivity
- Peak HRR: 8.6MW
- Fire location: WA = Warehouse A

Table 7.1: Fire scenarios

Input Parameters	
Scenario ID	**HP01C_8.6WA (Core Fire Scenario)**
Description:	First (1st) ring sprinkler controlled fire scenario • A mechanical failure or malfunction in one of the forklifts ignites the rack storage. The sprinkler system will activate as designed and control the fire. • The fire will grow at an ultra-fast t^2 rate and maintain its heat release rate upon activation of the sprinkler heads; hence the fire is not extinguished.
Fire Location:	Warehouse A
Fire Size	10.4MW
Intent	To evaluate the conditions within the Warehouse 1 with respect to occupant and fire fighter life safety.
Scenario ID	**HP02C_16.5WA (Sensitivity Fire Scenario)**
Description:	Second (2nd) ring sprinkler controlled fire scenario • A mechanical failure or malfunction in one of the forklifts ignites the rack storage. The sprinkler system will activate as designed and control the fire. • The fire will grow at an ultra-fast t^2 rate and maintain its heat release rate upon activation of the sprinkler heads; hence the fire is not extinguished.
Fire Location:	Warehouse A
Fire Size	16.5MW
Intent	To evaluate the conditions within the Warehouse 1 with respect to occupant and fire fighter life safety.
Scenario ID	**HP03C_8.6WD (Core Fire Scenario)**
Description:	First (1st) ring sprinkler controlled fire scenario • A mechanical failure or malfunction in one of the forklifts ignites the rack storage. The sprinkler system will activate as designed and control the fire. • The fire will grow at an ultra-fast t^2 rate and maintain its heat release rate upon activation of the sprinkler heads; hence the fire is not extinguished.
Fire Location:	Warehouse D
Fire Size	8.6MW
Intent	To evaluate the conditions within the Warehouse 3 with respect to occupant and fire fighter life safety.
Scenario ID	**HP04S_8.7WD (Sensitivity Fire Scenario)**
Description:	Forklift and pallet fuel-controlled fire scenario • An electrical malfunction of a forklift within the vicinity of the stacked pallets. The sprinkler system does not activate due to the limited heat produced as a result of the shielding provided by the machine and the distribution of combustible materials (a stack of pallets). • The fire will grow at a customised rate (similar to a fast t^2 fire growth rate). A decay phase shall follow as the fire is assumed to be fuel controlled.
Fire Location:	Warehouse D

Input Parameters	
Fire Size	8.7MW
Intent	To evaluate the conditions within the Warehouse 3A with respect to occupant and fire fighter life safety.

Fire Scenario Location Disclaimer

The fire scenarios detailed in Table 7.1 have been selected based on the worst credible scenario with respect to occupant and fire brigade life safety. This is based on the following salient points:

5. *The fire scenarios were selected within* ***Warehouse A*** *as it represents the largest warehouse with respect to building volume.*
    a. *As a conservative measure, the largest occupant population (i.e. 180 occupants - Section 2.2.2) has been adopted within Warehouse A for the purpose of the life safety analysis.*
6. *A fire scenario was selected within* ***Warehouse D*** *as it represents the smallest warehouse with respect to building volume.*
    a. *With a smaller building volume (i.e. smoke reservoir), the smoke layer is expected to descend quicker when compared to a larger warehouse; and therefore, it is expected to potentially compromise occupant and fire fighter life safety faster; and*
    b. *As a conservative measure, the largest occupant population (i.e. 160 occupants - Section 2.2.2) has been adopted within Warehouse D for the purpose of the life safety analysis.*

The outcomes for the adopted fire scenarios are representative for all other tenancies/warehouse buildings.

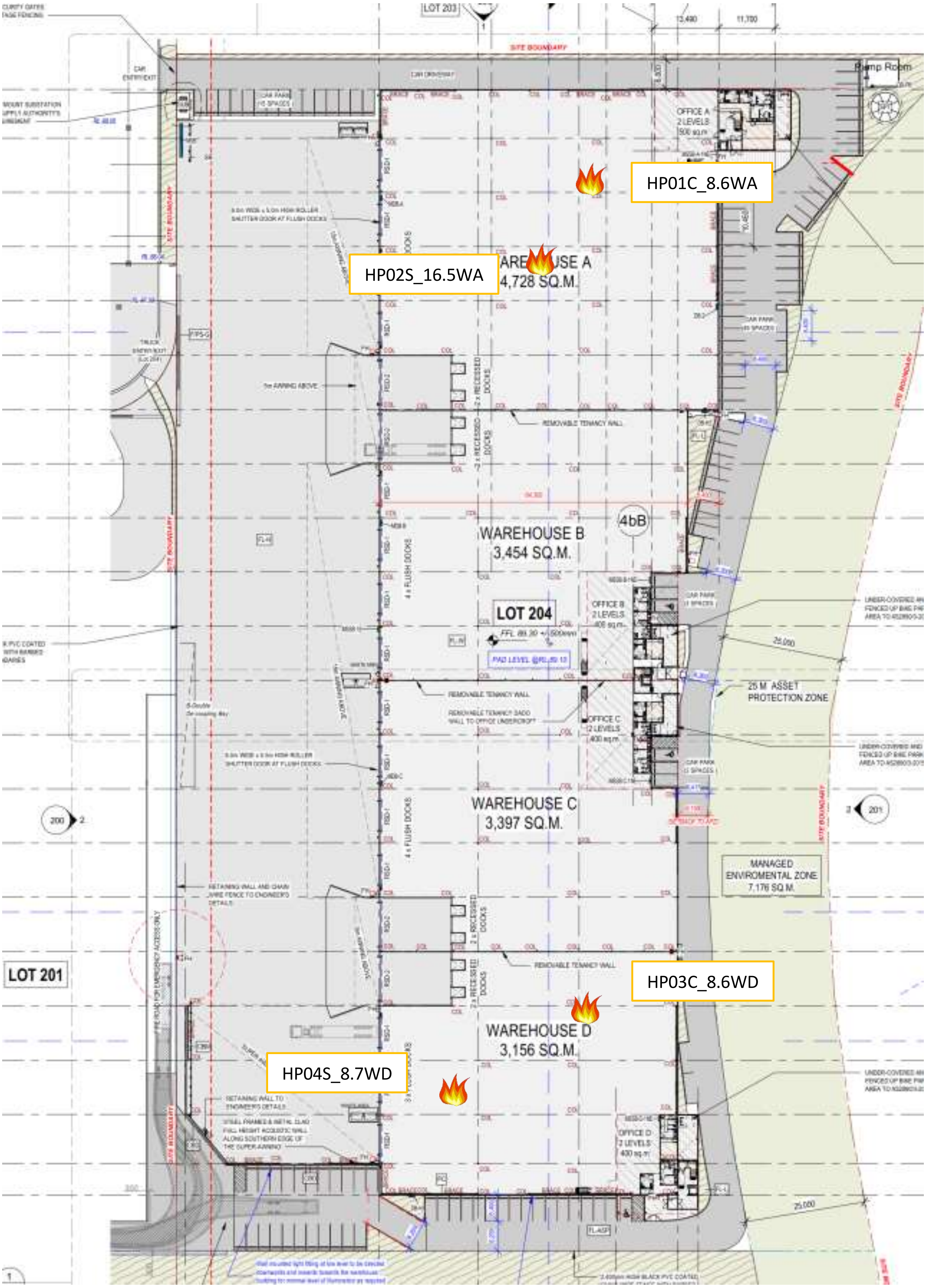


Figure 7.1: Design fire scenarios

7.3 Design Fire Scenarios

The design fire adopted for the identified fire scenarios having a potential to occur within the subject building must have consideration for the fuel load its orientation and the amount of ventilation. It should be noted that the building is to be provided with a sprinkler system throughout and therefore, it is more likely that within areas where sprinkler protection has been afforded the sprinklers will automatically operate and effectively control any potential fire and even suppress the fire as a result of the fast response sprinklers specifically designed, tested and approved for storage applications. Extensive studies carried out by a number of experts (including Hall, 2010) covering the past century of sprinkler protected buildings have confirmed that these systems are inherently reliable if well maintained and managed. Refer to Appendix D for further details.

It is unrealistic to adopt a single fire that represents the extreme worst case as the principal design fire and apply it to all fire scenarios modelled. It is considered that systems appropriately designed, commissioned and maintained would work as designed and hence the worst-case design fire would be a fire that did not take into account such systems. For example, in a building with sprinklers, the principal design fire would not be that in which sprinkler system failure is assumed. This scenario would be considered but the tenability criteria adopted for the assessment of this scenario may be less conservative than that adopted for the sprinkler affected fires. Using the worst-case scenario as the controlling design fire would lead to unacceptable and extremely conservative designs. Assessments conducted to consider the potential impact of fires which are more severe than the principal design fire may be used to assess the sensitivity of the performance solutions applied.

The design fire for any location is therefore considered the *worst credible* fire size given the nature of the fuel type and disposition and elements being assessed. Whilst there is a large amount of information concerning the burning rate of items, rarely is this information sufficiently generic to be universally adopted and what may be representative of current fuel loadings may not be the case in years to come. In any event it would be a rare assessment in which the specific items forming the fuel load had been tested to provide fire rate of heat release data.

7.3.1 Fire Growth Rates

In the standard fire growth rate curves the fires are classified by speed of growth. The fire growth rates are classified as ultra-fast, fast, medium and slow. The fire growth rates for different building materials are illustrated in Figure 7.2.

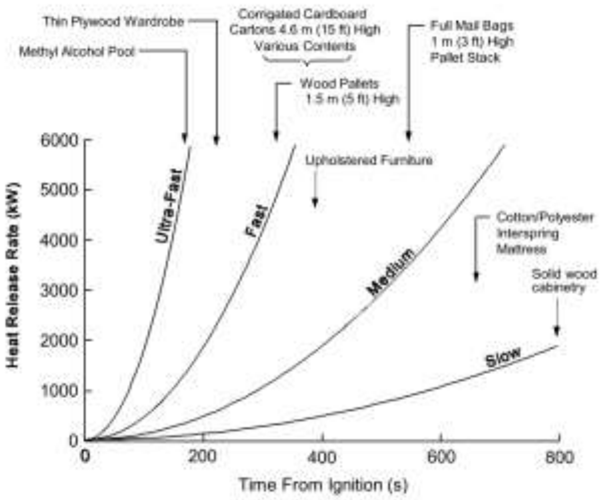


Figure 7.2: Standard Fire Growth Rate Curves (with some examples of fire test fuels) (NFPA)

In the development of credible design fires, the presence of automatic sprinklers has been considered. The main characteristics of the storage sprinkler system are that it is designed to not only control, but in most cases, extinguish a fire. In the case of other sprinkler systems, they are designed and installed based on the assumption that the system would only control the fire and limit fire spread beyond the area of first ignition.

Whilst determining credible design fires, a sprinkler-controlled design fire is assumed to remain at the heat release rate (HRR) following automatic sprinkler activation. With the suppression system, the fire may be modelled as decaying following the activation of the sprinklers to reflect the extinguishment capability of the system. The key design fire scenarios adopted for the core & sensitivity scenarios has been based on the following assumptions:

- The design fire comprises an ultra-fast t^2 fire growth rate. The t^2 fire growth rates is adopted as a global standard based on documents such as NFPA92, ISO TR 13388, Fire Engineering Design Guide (Buchanan) and BS476. The ultra-fast t^2 design fires reflect the extreme fuel type for commodities and distribution scenarios as listed in the tables below.

Table 1 Design fires as given in ISO TR 13388.

Design fire scenario	Category
Upholstered furniture and stacked furniture near combustible linings	*Ultra fast*
Light- weight furnishings	*Ultra fast*
Packing material in rubbish pile	*Ultra fast*
Non- fire retarded plastic foam storage	*Ultra fast*
Cardboard or plastic boxes in vertical storage arrangement	*Ultra fast*

Figure 7.3: Published Design Fire Growth Rates – ISO TR 13388

Fire growth rate	Growth time k (s)	Fire intensity coefficient α (MW/s²)	Typical real fire
Slow	600	.00293	Densely packed wood products
Medium	300	.0117	Solid wooden furniture such as desks Individual furniture items with small amounts of plastic
Fast	150	.0466	High stacked wood pallets Cartons on pallets Some upholstered furniture
Ultrafast	75	.1874	Upholstered furniture High stacked plastic materials Thin wood furniture such as wardrobes

Table 4.3: Typical growth times for design fires

Figure 7.4: Published Design Fire Growth Rates – Fire Engineering Design Guide (Buchanan)

It is noteworthy that that the ultra-fast t^2 design fires nominated within this report are assumed to be controlled by the sprinkler system and not extinguished hence, resulting in a significantly higher total energy release over the duration of the fire. Based on the likely commodities expected within the building and the aforementioned literature, the fire modelling undertaken shall consider fire scenarios adopting ultra-fast t^2 fire growth rates.

7.3.2 Credible Design Fire Locations and Scenarios

It must be noted that in the context of the subject warehouse, the ignition source statistics may need to be adjusted based on the fact that smoking is not allowed and strictly controlled. Also, it is not expected that hot works would not be carried out during operational hours. In environments where large numbers of occupants are present incendiary and suspicious fire lighting activities are not common. Based on these observations the most likely sources of ignition within the subject facility have been identified as:

1. Electrical malfunction such as with electrical lighting igniting combustible goods within storage racking arrangement.
2. Mechanical failure or malfunction (e.g. malfunction of a forklift) igniting nearby stored contents within the racking arrangement.

7.3.3 Methodology to Determine Sprinkler Activation Times

To determine the sprinkler activation time, Alpert's Correlation has been used based on the methodology prescribed by the IFEG (ABCB, 2005). The response equation for a heat detector head, or in this case a smoke detector, is given by the lumped mass heat transfer equation as follows:

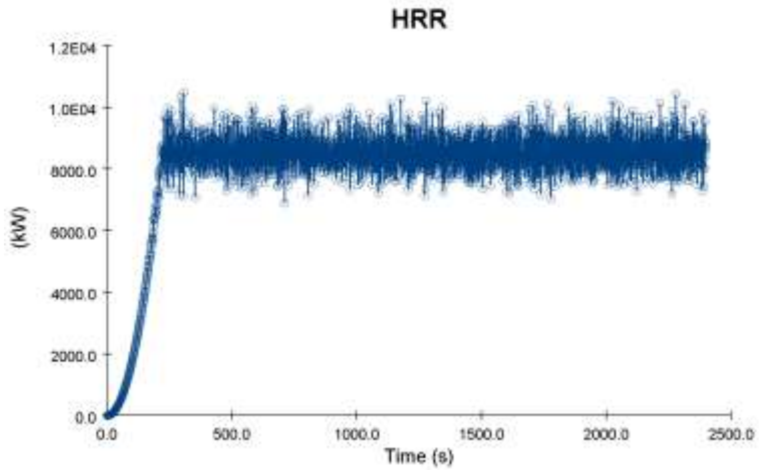
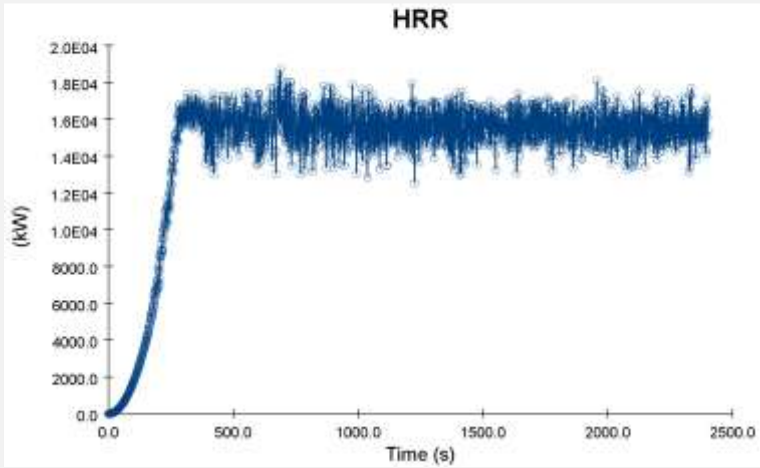
$$\frac{dT_d}{dt} = \frac{\sqrt{u} \times \left(T_g - T_d\right)}{RTI}$$

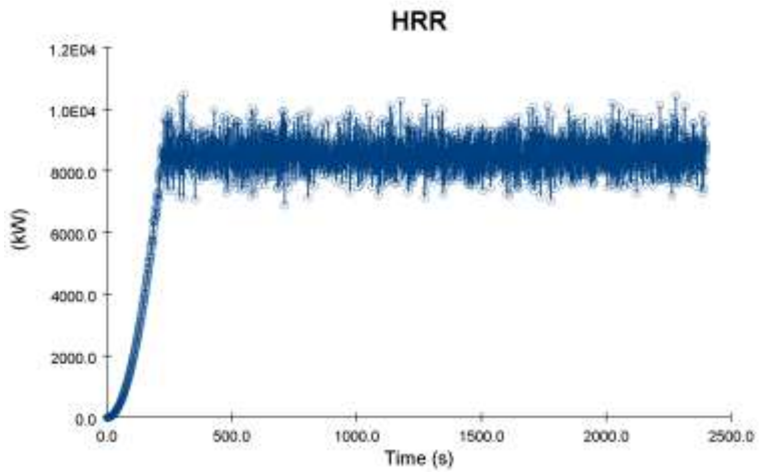
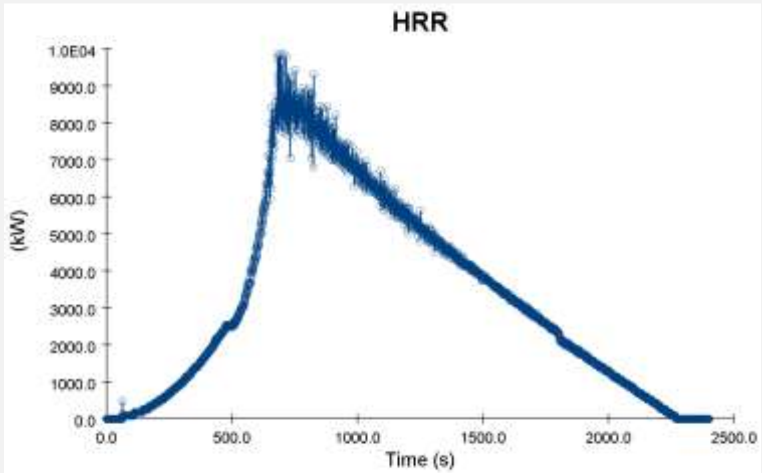
The formulas are calculated with reference to R.L. Alpert Fire Technology 1972 pp181-195.

7.3.4 Sprinkler Head Activation Parameters

The Storage Sprinkler head sprinkler shall be provided and has a Response Time Index (RTI) of $50m^{1/2}s^{1/2}$ and an actuation temperature (for analysis purposes) of 100˚C. Storage sprinkler systems are designed for use with storage heights of up to 12.2m and maximum ceiling heights of 13.7m. It is noted that the sprinkler activation time has been calculated using the 13.7m ridge height for this building. This method is the most conservative since it shall activate the sprinkler heads at the latest possible time and result in a larger fire size for each fire scenario. As the building is fitted with storage type sprinkles the core fire scenarios consist of fires that are controlled by the activation of sprinklers. In the scenario where sprinklers fail to activate or control the fire, and furthermore, the fire growth rate continues to increase to represent fuel-controlled burning.

Table 7.2: Summary of design fires and design fire scenarios

Design Fire Scenario	Description	System Operation	Fire Growth Rate	Peak HRR	Graphical representation of adopted design fire
HP01C_8.6WA ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(Core Scenario)*	Mechanical failure or malfunction of a forklift ignites the stacked storage The sprinkler system will activate as designed and control the fire. The fire will grow at an ultra-fast t^2 rate and maintain its heat release rate upon activation of the sprinkler heads.	Sprinkler system activates (1st ring) and controls at 218 seconds Sprinklers do not suppress the fire, but only control the fire growth rate being typically representative of steady state conditions.	Ultra-Fast t^2 fire	8.6MW	
HP02S_16.5WA ***Sprinkler delayed scenario*** *(2nd Ring Sprinkler Activation)* *(Sensitivity Scenario)*	Mechanical failure or malfunction of a forklift ignites the stacked storage The fire will grow at an ultra-fast t^2 rate and maintain its heat release rate upon activation of the second ring of the sprinkler heads; hence the fire is not extinguished.	Sprinkler system activates (2nd ring) and controls at 305 seconds Sprinklers do not suppress the fire, but only control the fire growth rate being typically representative of steady state conditions.	Ultra-Fast t^2 fire	16.5MW	

Design Fire Scenario	Description	System Operation	Fire Growth Rate	Peak HRR	Graphical representation of adopted design fire
HP03C_8.6WD ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(Core Scenario)*	Mechanical failure or malfunction of a forklift ignites the stacked storage The sprinkler system will activate as designed and control the fire. The fire will grow at an ultra-fast t^2 rate and maintain its heat release rate upon activation of the sprinkler heads.	Sprinkler system activates (1st ring) and controls at 218 seconds Sprinklers do not suppress the fire, but only control the fire growth rate being typically representative of steady state conditions.	Ultra-Fast t^2 fire	8.6MW	
HP04S_8.7WD ***Sprinkler Failure Scenario*** *(Sensitivity Scenario)*	An electrical malfunction of a forklift in the vicinity of combustible pallets which ignites. The fire shall grow at a customised rate which closely resembles a fast t^2 growth rate until the peak heat release rate (i.e. 8.7MW) is achieved. A decay phase shall follow as the fire is assumed to be fuel controlled.	The fire sprinkler system does not activate. The occupants become aware of the fire via visual cues.	Custom fire	8.7MW	

7.4 Evacuation Scenarios

For the assessment of the occupant movement during fires within the warehouse Pathfinder human movement simulation software is adopted as the computer evacuation modelling tool.

Pathfinder models movement of people in a building. It is based on real human behaviour, using data gathered from video analysis of individuals moving in crowds. Research results from around the world are used to augment the data, giving a unique level of accuracy and an unmatched capability for simulating building evacuation.

Two (2) types of evacuation models have been constructed for the purposes of the assessment. Based on the location of the design fires, the evacuation models has considered the following scenarios:

1. **Core Evacuation Scenario**
    a. The building has a full occupant loading.
    b. All exits are available and assumed to be clear/free of obstruction
    c. Occupant pre-movement times (risk contour methodology) have been implemented to the evacuation analysis.
2. **Sensitivity Evacuation Scenario**
    a. The building has a full occupant loading.
    b. All exits are available and assumed to be clear/free of obstruction , with the exception of the following:
        i. Exit closest to the fire are deemed unavailable (refer to Figure 7.5)
        ii. Occupants are required to seek alternative exits.
    c. Occupant pre-movement times (risk contour methodology) have been implemented to the evacuation analysis.

Figure 7.5: Combined design fire & evacuation scenarios

7.5 Overview of Design Fire & Evacuation Scenarios

For the assessment of the subject building, the fire and smoke spread model FDS has been used to model the fire scenarios within a representative main warehouse portion of the subject building. The following evacuation modelling has been undertaken based on the design fire scenarios presented below. A summary of the proposed design fires and fire scenarios are listed in Table 7.3.

Table 7.3: Summary of adopted fire & evacuation scenarios

Combined Scenario	Fire Scenario	System Activation	Evacuation Scenario Available Exits
HP01C_8.6WA: Sprinkler Controlled Storage Rack Fire	In storage rack fire and potentially spreading to other boxed items Growth Rate: Ultra-Fast t^2 Fire Size: 8.6MW ***Core Fire Scenario***	Sprinkler system activates and controls fire at 218 sec Sprinklers do not suppress the fire, but only control the fire growth rate being typically representative of steady state conditions. Occupant evacuation commences off sprinkler activation or visual cues (whichever occurs first).	***Core Evacuation Scenario***: The building has a full occupant loading and all exits are available. All exits are available and assumed to be clear/free of obstruction. Occupants evacuate after fire detection (visual cue or via sprinkler activation, whichever is first) and pre-movement delays.
			Sensitivity Evacuation Scenario: The building has a full occupant loading. Exits located in warehouse 1 (i.e. within the north side) are blocked assuming the exits are inaccessible in this area. The blocked exits and potential egress paths reduce the number of available exits. The building occupants are therefore required to travel to the next safe available exit. Occupants evacuate after fire detection (visual cue or via sprinkler activation, whichever is first) and pre-movement delays.
HP02S_16.5WA: Sprinkler Controlled Storage Rack Fire	In storage rack fire and potentially spreading to other boxed items Growth Rate: Ultra-Fast t^2 Fire Size: 16.5MW ***Sensitivity Fire Scenario***	Sprinkler system activation is delayed (i.e. 2nd ring) and controls fire at 305 sec Sprinklers do not suppress the fire, but only control the fire growth rate being typically representative of steady state conditions Occupant evacuation commences based off the sprinkler activation or visual cues (whichever occurs first).	***Core Evacuation Scenario***: The building has a full occupant loading and all exits are available. All exits are available and assumed to be clear/free of obstruction. Occupants evacuate after fire detection (visual cue or via sprinkler activation, whichever is first) and pre-movement delays.
HP03C_8.6WD: Sprinkler Controlled Storage Rack Fire	In storage rack fire and potentially spreading to other boxed items Growth Rate: Ultra-Fast t^2 Fire Size: 8.6MW ***Core Fire Scenario***	Sprinkler system activates and controls fire at 218 sec Sprinklers do not suppress the fire, but only control the fire growth rate being typically representative of steady state conditions. Occupant evacuation commences off sprinkler	***Core Evacuation Scenario***: The building has a full occupant loading and all exits are available. All exits are available and assumed to be clear/free of obstruction. Occupants evacuate after fire detection (visual cue or via sprinkler activation, whichever is first) and pre-movement delays.

Combined Scenario	Fire Scenario	System Activation	Evacuation Scenario Available Exits
		activation or visual cues (whichever occurs first).	***Sensitivity Evacuation Scenario:*** The building has a full occupant loading. Exits located in warehouse 3 (i.e. within the west side) are blocked assuming the exits are inaccessible in this area. The blocked exits and potential egress paths reduce the number of available exits. The building occupants are therefore required to travel to the next safe available exit. Occupants evacuate after fire detection (visual cue or via sprinkler activation, whichever is first) and pre-movement delays.
HP04S_8.7WD: Fuel Controlled Forklift & Storage Pallet Fire	A forklift fire is considered to initiate before spreading to a nearby stack of timber storage pallets. The fire begins to decay following the peak heat release rate (PHRR). Custom Growth Rate Fire Size: 8.7MW ***Core Fire Scenario***	Sprinkler activation is not considered to occur. Occupant evacuation commences based off visual cues.	***Core Evacuation Scenario***: The building has a full occupant loading and all exits are available. All exits are available and assumed to be clear/free of obstruction. Occupants evacuate after fire detection (visual cue or via sprinkler activation, whichever is first) and pre-movement delays.

8. Life Safety Analysis

8.1 General

The Life Safety Analysis (ASET/RSET) has been undertaken to determine the acceptability of the trial design which includes design issues that specifically relate to egress provisions and smoke hazard management design. To address these issues a holistic approach has been undertaken with consideration of the fire safety systems installed within the building to ensure tenability limits are not breached during the evacuation process.

8.2 Evacuation Analysis to Determine RSET

An evaluation of the evacuation time phases (fire detection, occupant pre-movement and occupant movement) has been undertaken to calculate the RSET. The main occupant group associated with a development of this nature are identified as staff and compromise persons from varying gender and age groups with a more uniform level of physical and mental ability. The proposed method adopted for determining each component is briefly described in the following subsections.

8.2.1 Detection Time

The detection time has been based on either the time required for the automatic sprinkler system to operate within the facility and/or the time for building occupants to detect the fire/smoke via olfactory and visual cues. The sprinkler activation time for each fire scenario, with the exception of the HP04S_8.7WD scenario, has utilised a spread sheet calculation which incorporates Alpert's Correlation (refer to Appendix H). The detection time was based on the ceiling heights of the building (i.e. 13.7m in the main storage and process areas); and adopted sprinkler system (i.e. activation temperature of 100°C and RTI of $50m^{-0.5}s^{-0.5}$). Refer to Appendix HAppendix F for the details of the input parameters and output results for each of the detection times. Furthermore, with reference to Clause 8.13.1 of AS2118.1:2017, the delay times to depressurise the sprinkler system is in the order of 180 seconds.

Furthermore, the FDS modelling outcomes have demonstrated that occupant visual cues are expected to occur significantly quicker than the time for the sprinkler to activate. Based on the studies conducted in 'Microeconomics Reform: Fire Regulation' (BRR, 1991), the time that the smoke layer drops 5% from the ceiling height is the visual smoke detection time by occupants. For conservatism, the detection time (occupant visual cues) has been based on the time for the smoke layer to drop 10% from the ceiling height over approximately 50% of the total floor area. Refer to Figure 8.1 to Figure 8.3 for the FDS modelling outcomes for occupant visual cues to occur. A summary of the detection time for each modelled scenario is noted to be as per Table 8.1.

Table 8.1: Allocated Detection times for the adopted design fire scenarios

Design Fire Scenario	Fire Location	Sprinkler Activation (Refer to Appendix H)	Occupant Visual Cue (Refer to FDS outcomes)
HP01C_8.6WA ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(**Core Scenario**)*	Warehouse A	398 seconds (218 + 180)	60 seconds
HP02S_16.5WA ***Sprinkler delayed scenario*** *(2nd Ring Sprinkler Activation)* *(**Sensitivity Scenario**)*	Warehouse A	485 seconds (305 + 180)	60 seconds
HP03C_8.6WD ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(**Core Scenario**)*	Warehouse D	398 seconds (218 + 180)	60 seconds
HP04S_8.7WD ***Sprinkler Failure Scenario*** *(**Sensitivity Scenario**)*	Warehouse D	N/A (sprinkler Failure)	125 seconds

Note: *It is noted that the detection time within the area of fire origin of fire scenarios HP01C_8.6WA, HP02S_16.5WA and HP03C_8.6WD has been based on occupant visual and olfactory cues, while the remaining enclosures' detection time shall rely on sprinkler activation.*

Note: *It is noted that the detection time within the area of fire origin of fire scenario HP04S_8.7WD, is based on occupant visual and olfactory cues. It is noted that the fire scenario adopts a custom fire similar to a fast t^2 fire with no sprinkler activation or associated automatic detection activation given the nature and size of the fire selected. In this instance, the detection time for the remaining enclosures (i.e. non-fire affected areas) of the building has been based on the total evacuation time within the area of fire origin + notification time to the occupants in the remaining enclosures (i.e. non-fire affected areas).*

Figure 8.1: Time for occupant visual detection cues to occur (HP01C_8.6WA, 60 seconds)

Figure 8.2: Time for occupant visual detection cues to occur (HP02S_16.5WA, 60 seconds)

Figure 8.3: Time for occupant visual detection cues to occur (HP03C_8.6WD, 60 seconds)

Figure 8.4: Time for occupant visual detection cues to occur (HP04S_8.7WD, 125 seconds)

8.2.2 Pre-Movement Time

The pre-movement component of the evacuation process as previously stated often has the greatest variability as occupant located within the direct vicinity of the fire will become aware of a fire and will start their movement phase more rapidly hence these occupants would have a reduced pre-movement time.

Similarly, occupants located remote from the fire will take considerably longer to decide on an appropriate course of action as a result of the fire not being a direct threat hence occupants further away from the fire will have an increased pre-movement time. This phenomenon has been considered in the occupant evacuation analysis.

Pre-movement times are established based on an analysis and interpretation of human behaviour studies from the literature and BS7974-2001 “Application of fire safety engineering principles to the design of buildings – Code of Practice”.

In the immediate area where the fire initiates occupants are assumed to have a corresponding risk (i.e. IR1) which is expected to be higher than all other areas within the building. The surrounding areas would naturally have a relatively lower level of risk (i.e. IR2, IR3, IRn). Therefore, a contoured approach is considered a reasonable assumption. Based on the above, the following pre-movement times are considered appropriate for the evacuation analysis:

Occupancies such as the warehouse are highly appropriate for adopting the risk contours approach. Visual access to other section of the building is not always assured. Hence, in the event of a fire in one particular area the occupants within the immediate vicinity would become aware of the fire immediately while occupants located in other part would rely on secondary warnings such as alarms, staff or other occupants moving away from the zone of fire origin. The pre-movement time would incrementally increase for zones further away from the area of fire origin (AFO).

With reference to the Fire Safety Science- Proceedings of the Tenth International Symposium, studies have indicated that the pre-movement time for industrial buildings vary between 30 seconds to 30 minutes depending on the management level, alarm level and building complexity of the development. Table 8.2 provides a pre-movement times for a typical industrial building.

Table 8.2: Suggested pre-movement times from PH7974-6:2019 (abstracted from Fire Safety Science- Proceedings of the Tenth International Symposiums)

Scenario Category	First Occupants (mins)	Occupant Distribution (mins)
Awake and familiar (Industrial, office, etc)		
M1 (B1-B2) (A1 – A2)	0.5	1.5
M2 (B1-B2) (A1 – A2)	1.0	3.0
M3 (B1-B2) (A1 – A3)	>15	>30

Note:

M1 would normally require voice alarm/PA if unfamiliar visitors likely to be present

For B3, add 0.5 for wayfinding

Definitions:

Management Level

M1: Occupants (staff) should be trained to a high level of fire safety management.

M2: Similar to M1 but lower staff ratio and floor wardens not always present.

M3: Basic management with minimum fire safety management.

Alarm Level

A1: Automatic detection throughout the building activating an immediate general alarm to all occupants.

A2: Automatic detection throughout the building providing a pre-alarm to management with a manually activated general fire alarm.

A3: Local automatic detection and alarm only near location of the fire or no automatic detection with manually activated general alarm.

Building Complexity

B1: Simple rectangular single storey building with on or few enclosures and simple layout.

B2: Simple multi-enclosure (usually multi-storey) building and simple internal layout.

B3: Large complex building where occupants may have way finding difficulties.

In the context of the warehouse, the building has been divided into intervals according to the configuration and internal layout. The pre-movement times for the evacuation scenarios are as follows:

- IR1: The pre-movement time for the immediate tenancy of fire origin (AFO) is 30 seconds; and
- IR2: The pre-movement time for the adjacent tenancy of fire origin is 90 seconds; and
- IR3: The pre-movement time for the non-fire affected warehouses is 180 seconds.

8.2.3 Movement Time

A comprehensive people movement model has been constructed for the warehouse portion. For further details of the 3D Human Movement Simulation modelling refer to Appendix G. A number of separate evacuation models have been constructed for the purpose of the assessment and more over to develop a degree of conservatism within the design. While the exit paths of travel require the occupants to travel to the designated exits and then discharge to the open space, in order to demonstrate levels of redundancy consideration was given to cases where a potential fire may block an exit.

Occupant numbers are based on the information provided by the client to accommodate for a total of 660 occupants (employees and visitors) across the site distributed as specified in Section 2.2.2. A conservative approach to the occupant numbers and distribution was adopted with the occupants of the office portions being distributed throughout the rest of the facility which have been considered as having higher risk of fire ignition.

The following tables are a summary of the evacuation time results from the Pathfinder software output file. Note that the pre-movement time has been incorporated into the Pathfinder software. A detailed copy of the evacuation modelling output is provided in Appendix G.

Table 8.3: Occupant movement times for adopted evacuation scenarios

Applicable Design Fire Scenario	Evacuation Scenario	Area	Occupant Numbers	$T_{pm} + T_m$ (seconds)
HP01C_8.6WA ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(Core Scenario)*	**ES01C** All exits available *(Core Scenario)*	Warehouse A	180 people	160
	ES01S Exits within vicinity of fire unavailable *(Sensitivity Scenario)*	Warehouse A	180 people	175
HP02S_16.5WA ***Sprinkler delayed scenario*** *(2nd Ring Sprinkler Activation)* *(Sensitivity Scenario)*	**ES02C** All exits available *(Core Scenario)*	Warehouse A	180 people	150
HP03C_8.6WD ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(Core Scenario)*	**ES03C** All exits available *(Core Scenario)*	Warehouse D	160 people	145
	ES03S Exits within vicinity of fire unavailable *(Sensitivity Scenario)*	Warehouse D	160 people	155
HP04S_8.7WD ***Sprinkler Failure Scenario*** *(Sensitivity Scenario)*	**ES04C** All exits available *(Core Scenario)*	Warehouse D	160 people	145

Note:

8.2.4 Total RSET

Combining all the elements of the evacuation process timeline as calculated in the aforementioned sections of this report gives the overall Required Safe Egress Time (RSET) as detailed in Table 8.4. Graphic modelling outcomes for occupant movement simulations (Pathfinder) are depicted in Appendix G.

Table 8.4: Calculated RSET

Design Fire Scenario	Evacuation Scenario	Area	RSET Based on Location (seconds)		
			T_d	$T_{pm} + T_m$	*RSET*
HP01C_8.6WA ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(Core Scenario)*	**ES01C** All exits available *(Core Scenario)*	Warehouse A	60	160	220
	ES01S Exits within vicinity of fire unavailable *(Sensitivity Scenario)*	Warehouse A	60	175	235
HP02S_16.5WA ***Sprinkler delayed scenario*** *(2nd Ring Sprinkler Activation)* *(Sensitivity Scenario)*	**ES02C** All exits available *(Core Scenario)*	Warehouse A	60	150	210
HP03C_8.6WD ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(Core Scenario)*	**ES03C** All exits available *(Core Scenario)*	Warehouse D	60	145	205
	ES03S	Warehouse D	60	155	215

Design Fire Scenario	Evacuation Scenario	Area	RSET Based on Location (seconds)		
			T_d	***T_{pm} + T_m***	***RSET***
	Exits within vicinity of fire unavailable (*Sensitivity Scenario*)				
HP04S_8.7WD ***Sprinkler Failure Scenario*** (*Sensitivity Scenario*)	**ES04C** All exits available (*Core Scenario*)	Warehouse D	125	145	270

Note: *It is noted that the detection time within the area of fire origin of fire scenario HP04S_8.7WD, has been based on occupant visual and olfactory cues. It is noted that the fire scenario adopts a custom fire similar to a fast t^2 fire with no sprinkler activation or associated automatic detection activation given the nature and size of the fire selected. In this instance, the detection time for the remaining enclosures (i.e. non-fire affected areas) of the building has been based on the total evacuation time within the area of fire origin + notification time to the occupants in the remaining enclosures (i.e. non-fire affected areas).*

8.3 Smoke Modelling Analysis to Determine ASET

Based upon the smoke modelling conducted, Table 8.5 provides an understanding of the outcomes of each model. The table specifically details the major occurrences in relation to the acceptance criteria as detailed in Section 5 of this report. Graphic modelling outcomes are depicted in Appendix F.

Table 8.5: Design fire scenario discussion

Design Fire Scenario	Design Fire Scenario Summary	Layer Height and Temperature at the Conclusion of the Modelling
HP01C_8.6WA ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* (*Core Scenario*)	In storage rack fire and potentially spreading to other boxed items Growth Rate: Ultra-Fast t^2 Fire Size: 8.6MW ***Core Fire Scenario***	**System Activation:** Sprinkler activates and controls the fire at 398 seconds. **Occupant Visual Cues:** It was observed that the smoke layer spread over approximately 50% of the roof/ceiling and dropped approximately 10% below the roof/ceiling at 60 seconds for occupant visual cues to occur. **Occupant Tenability Criteria:** **Visibility:** The model demonstrated acceptable tenable conditions within the visibility acceptance criteria (i.e. visibility >10m) within the warehouse area being maintained up to 800 seconds. **Convective Heat:** The smoke layer temperature (below 2.0m above the finished floor level) did not exceed 60°C for durations greater than 2700 seconds due to the convection of cool air (i.e. the building volume). **Conclusion:** Visibility at 10m was the first tenability criteria and has been breached at 800 seconds. As such, the ASET for the sprinkler-controlled fire scenario have been determined.

Design Fire Scenario	Design Fire Scenario Summary	Layer Height and Temperature at the Conclusion of the Modelling
HP02S_16.5WA ***Sprinkler delayed scenario*** *(2nd Ring Sprinkler Activation)* *(**Sensitivity Scenario**)*	In storage rack fire and potentially spreading to other boxed items Growth Rate: Ultra-Fast t^2 Fire Size: 16.5MW ***Sensitivity Fire Scenario***	**System Activation:** Sprinkler activates and controls the fire at 485 seconds. **Occupant Visual Cues:** It was observed that the smoke layer spread over approximately 50% of the roof/ceiling and dropped approximately 10% below the roof/ceiling at 60 seconds for occupant visual cues to occur. **Occupant Tenability Criteria:** **Visibility:** The model demonstrated acceptable tenable conditions within the visibility acceptance criteria (i.e. visibility >10m) within the warehouse area being maintained up to 450 seconds. **Convective Heat:** The smoke layer temperature (below 2.0m above the finished floor level) did not exceed 60°C for durations greater than 2700 seconds due to the convection of cool air (i.e. the building volume). **Conclusion:** Visibility at 10m was the first tenability criteria and has been breached at 450 seconds. As such, the ASET for the sprinkler-controlled fire scenario have been determined.
HP03C_8.6WD ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(**Core Scenario**)*	In storage rack fire and potentially spreading to other boxed items Growth Rate: Ultra-Fast t^2 Fire Size: 8.6MW ***Core Fire Scenario***	**System Activation:** Sprinkler activates and controls the fire at 398 seconds. **Occupant Visual Cues:** It was observed that the smoke layer spread over approximately 50% of the roof/ceiling and dropped approximately 10% below the roof/ceiling at 60 seconds for occupant visual cues to occur. **Occupant Tenability Criteria:** **Visibility:** The model demonstrated acceptable tenable conditions within the visibility acceptance criteria (i.e. visibility >10m) within the warehouse area being maintained up to 500 seconds. **Convective Heat:** The smoke layer temperature (below 2.0m above the finished floor level) did not exceed 60°C for durations greater than 2700 seconds due to the convection of cool air (i.e. the building volume). **Conclusion:** Visibility at 10m was the first tenability criteria and has been breached at 500 seconds. As such, the ASET for the sprinkler-controlled fire scenario have been determined.
HP04S_8.7WD ***Sprinkler Failure Scenario*** *(**Sensitivity Scenario**)*	A forklift fire is considered to initiate before spreading to a nearby stack of timber storage pallets. The fire begins to decay following the peak heat release rate (PHRR). Custom Growth Rate Fire Size: 8.7MW ***Core Fire Scenario***	**System Activation:** N/A. **Occupant Visual Cues:** It was observed that the smoke layer spread over approximately 50% of the roof/ceiling and dropped approximately 10% below the roof/ceiling at 125 seconds for occupant visual cues to occur. **Occupant Tenability Criteria:** **Visibility:** The model demonstrated acceptable tenable conditions within the visibility acceptance criteria (i.e. visibility >10m) within the warehouse area being maintained up to 825 seconds. **Convective Heat:** The smoke layer temperature (below 2.0m above the finished floor level) did not exceed 60°C for durations greater than 2700 seconds due to the convection of cool air (i.e. the building volume). **Conclusion:** Visibility at 10m was the first tenability criteria and has been breached at 825 seconds. As such, the ASET for the sprinkler-controlled fire scenario have been determined.

The values listed in Table 8.6 are based upon the time at which the acceptance criteria were satisfied or alternatively the time at which the model simulation was completed and steady state conditions within the enclosure were observed. The tenability conditions have not been breached during the simulation time of 2700 seconds. Table 8.6 provides a summary of the ASET values determined as a result of the analysis.

Table 8.6: Summary of ASET values

Design Fire Scenario	Fire Location	ASET (seconds)
HP01C_8.6WA ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* ***(Core Scenario)***	Warehouse A	800
HP02S_16.5WA ***Sprinkler delayed scenario*** *(2nd Ring Sprinkler Activation)* ***(Sensitivity Scenario)***	Warehouse A	450
HP03C_8.6WD ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* ***(Core Scenario)***	Warehouse D	500
HP04S_8.7WD ***Sprinkler Failure Scenario*** ***(Sensitivity Scenario)***	Warehouse D	825

Note: *The graphical modelling outputs for each fire scenario are provided in Appendix F. The fire models were terminated at 2700 seconds as conditions maintained steady state.*

8.4 Evaluation of Results

8.4.1 Occupant Life Safety Summary

From the above analysis, the indication of the life safety of the occupants can be obtained by comparison of the ASET and RSET values for the scenarios examined (this comparison is provided in Table 8.7). Similarly, with consideration to the FBIM conducted in Section 6.

Based on the fire and evacuation modelling undertaken tenable conditions are maintained for a period greater than the required time with a sufficient safety factor. This value is greater than the time for Fire Brigade intervention undertaken (i.e. 2697 seconds). Hence, the acceptance criteria are considered to be satisfied and met (this comparison is provided in Table 8.8).

Table 8.7: ASET/RSET comparison for building occupants

Modelled Design Fire	Evacuation Scenario	Area	RSET (seconds)	ASET (seconds)	Factor of Safety (ASET/RSET)	Acceptance Criteria Satisfied
HP01C_8.6WA ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(Core Scenario)*	**ES01C** All exits available *(Core Scenario)*	Warehouse A	220	800	3.64	YES
	ES01S Exits within vicinity of fire unavailable *(Sensitivity Scenario)*	Warehouse A	235	800	3.40	YES
HP02S_16.5WA ***Sprinkler delayed scenario*** *(2nd Ring Sprinkler Activation)* *(Sensitivity Scenario)*	**ES02C** All exits available *(Core Scenario)*	Warehouse A	210	450	2.14	YES

Modelled Design Fire	Evacuation Scenario	Area	RSET (seconds)	ASET (seconds)	Factor of Safety (ASET/RSET)	Acceptance Criteria Satisfied
HP03C_8.6WD ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(Core Scenario)*	**ES03C** All exits available *(Core Scenario)*	Warehouse D	205	500	2.44	YES
	ES03S Exits within vicinity of fire unavailable *(Sensitivity Scenario)*	Warehouse D	215	500	2.33	YES
HP04S_8.7WD ***Sprinkler Failure Scenario*** *(Sensitivity Scenario)*	**ES04C** All exits available *(Core Scenario)*	Warehouse D	270	825	3.06	YES

8.4.2 FBIM Summary

Table 8.8: ASET/FBIM comparison for attending fire crews

Modelled Design Fire Scenario	Attending Fire Brigade	Fire Brigade Intervention (seconds)	Fire-Fighter ASET (seconds)	Acceptance Criteria Satisfied
HP01C_8.6WA ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(Core Scenario)*	Huntingwood Fire Station	2349	Routine conditions: >2700	YES
	Bonnyrigg Heights Fire Station	2529	Routine conditions: >2700	YES
HP02S_16.5WA ***Sprinkler delayed scenario*** *(2nd Ring Sprinkler Activation)* *(Sensitivity Scenario)*	Huntingwood Fire Station	2349	Routine conditions: >2700	YES
	Bonnyrigg Heights Fire Station	2529	Routine conditions: >2700	YES
HP03C_8.6WD ***Sprinkler Controlled Scenario*** *(1st Ring Sprinkler Activation)* *(Core Scenario)*	Huntingwood Fire Station	2349	Routine conditions: >2700	YES
	Bonnyrigg Heights Fire Station	2529	Routine conditions: >2700	YES
HP04S_8.7WD ***Sprinkler Failure Scenario*** *(Sensitivity Scenario)*	Huntingwood Fire Station	2349	Routine conditions: >2700	YES
	Bonnyrigg Heights Fire Station	2529	Routine conditions: >2700	YES

Note: *At the completion of the fire and smoke modelling simulations (i.e. 2700s), the temperature conditions maintained at steady state conditions. In this regard, it is expected that the safety factor of 1.5 has been achieved for fire-fighter life safety (i.e. temperatures do not exceed 100°C at 1.5m above the finished floor level for routine conditions).*

The Fire Brigade Intervention Model (FBIM) estimates the time for applying water onto a fire in addition to arriving at kerb side is in the order of 2529 seconds or approximately 42 minutes. In relation to Fire Brigade intervention, the model simulations were completed at 2700 seconds and demonstrated steady state conditions whereby temperatures did not exceed 100°C at 1.5m above the finished floor level for all adopted fire scenarios. Therefore, on-going routine (steady state) conditions were provided for the attending Fire Brigades. It is not expected that the conditions (i.e. temperature) would worsen beyond 2700 seconds. This is a result of the upper (hot) smoke layer mixing with the lower (cool) smoke layer (i.e. convection). Section 5 provides evidence that the temperature criteria within the warehouse for all scenarios are well below 100°C.

Based on the outcomes of the quantitative fire and occupant evacuation modelling it is clearly demonstrated that the proposed suite of fire safety systems achieves adequate levels of life safety to ensure that occupants are able to safely evacuate from the building an attending fire-fighter are provided with adequate conditions to undertake Standard Operational Guideline's (SOG's). In all instances presented above, the established acceptance criteria as stated in Section 5 of this report have been satisfied.

9. External Awning Located within Minimum Setback Distances to Title Boundaries

9.1 Background to the Issue

It has been identified that the super awnings located along the western portion of the building form part of the external wall and are located within close proximity to the title boundary (within 3.0m) without the required fire rating pursuant to Type C fire resisting construction.

Furthermore, it is proposed to permit the openings associated with the super awnings to be located within 3.0m from the title boundary.

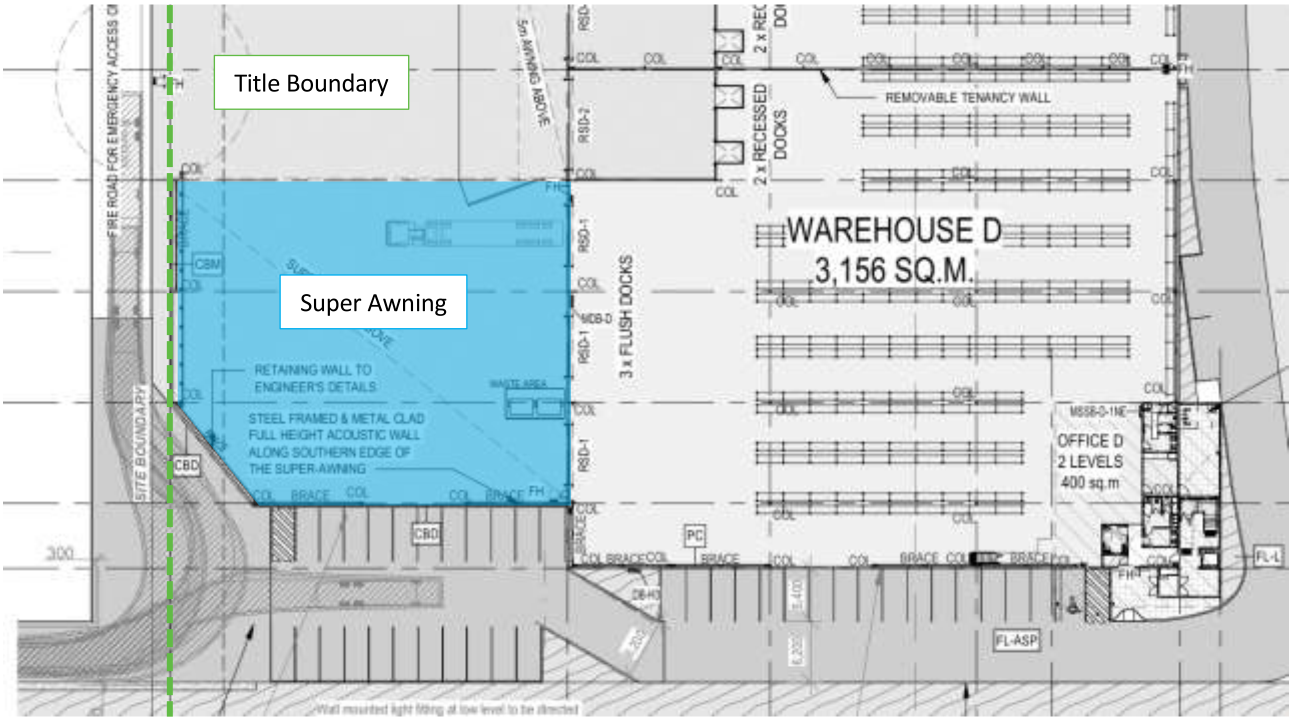


Figure 9.1: Location of super awning with respect to title boundary

9.2 NCC Assessment Methodology

In accordance with the BCA Clause A2.2 *Assessment Methods* the following assessment method has been adopted to determine that the *Performance Solution* has met the relevant *Performance Requirements* CP1 & CP2.

Table 9.1: Methods of Analysis

Identified Design Issue	BCA Assessment Method	IFEG Method of Analysis
It has been identified that the super awnings located along the western portion of the building form part of the external wall and are located within close proximity to the title boundary (within 3.0m) without the required fire rating pursuant to Type C fire resisting construction.	A2.2(2)(b)(ii) such other *Verification Methods* as the *appropriate authority* accepts for determining compliance with the *Performance Requirements*.	A qualitative approach to determine whether the performance solution satisfies the intent and complies with the Performance Requirements.

9.3 Hazard Specific External Awnings Located within Minimum Setback Distance to Title Boundaries

The Guide to the BCA (ABCB, 2019) states that the intent associated with the prescribing a minimum distance where external walls are to be located as being "*To have an FRL and prevent the spread of fire from the boundary of an adjoining allotment, or one building to another building on the same allotment".* With respect to the proposed development the hazard analysis illustrates a number of consistent observations. These include the following:

- The potential for fire spread to the adjacent property.

- The proposed FRL may potentially have a negative impact on the life safety and occupants and Fire Brigade Intervention.

9.4 Hazard Mitigation

The Guide to the BCA (ABCB, 2019) identifies the potential for fire spread from a fire source feature to the subject building via the non-fire rated external wall (i.e. external canopies). In this regard the following hazard mitigation systems, requirements and features of the design are noted:

- The entire building shall be provided with automatic fire sprinkler protection in accordance with AS 2118.1:2017. The sprinkler system shall be as follows:
  - The Class 5 office portion of the subject building is to be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 appropriate to 'Light Hazard' classification; and
  - The Class 7b warehouse portion of the subject building is to be sprinkler protected with the installation of K22 Storage Sprinkler or equivalent incorporating 'fast response' type heads. The activation temperature of Storage sprinkler heads shall be no more than 100°C; and
  - Covered awnings forming part of the Class 7b portion of the subject building shall be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 to 'Ordinary Hazard 3' classification unless otherwise Storage Sprinklers are proposed; and
- To permit the non-loadbearing super awnings located along the western portion of the building form part of the external wall to be located within 3.0m from the title boundary without the required FRL specified under Table 5 of Specification C1.1. The identified super awnings shall be designed and constructed utilising materials and building elements deemed non-combustible when tested to AS1530.1:1994 or as per BCA C1.12; and
- Permit the openings associated with the super awnings to be located within 3.0m from the title boundary; and
- The area/space beneath the super awnings have limited ignition sources and fuel loads as it is not likely to contain any permanent storage.

9.5 Methodology

The methodology adopted to address the proposed FRL to the super awnings located along the western portion of the building was a qualitative comparative assessment. The assessment has considered the presence of the PVA track separating buildings on the same site, and the resulting distance between external walls of the subject buildings being comparable to the DtS provisions of the BCA.

9.6 Acceptance Criteria

The basic objective and intent of this analysis pertains to the potential for fire-spread between the subject building and the title boundary. Thus, the primary acceptance criterion has been met by demonstrating that the design is equivalent to a deemed-to-satisfy compliant design with respect to fire spread and with consideration to the presence of the PVA track separating buildings on the same.

9.7 Evaluation of External Awnings Located within Minimum Setback Distance to Title Boundaries

The issue relates to fire spread via the external canopies, hence this assessment will consider both fire spread from the adjacent title boundary to the subject building, and from the subject building to the adjacent title boundary.

The identified external canopies are proposed to be designed and constructed utilising materials and building elements deemed non-combustible when tested to AS1530.1:1994 or as per Clause C1.12 from Volume One of the NCC. This shall ensure that the canopies are non-combustible, such that they do not have the potential to add to the fuel load and hence the size of the any potential fire, and that they cannot be ignited by flames, radiant heat or embers originating from the adjacent property. In this way, the non-combustible external canopies shall not contribute to any increased risk of fire spread.

In addition, the area under the awning forms part of the vehicular access around the subject site. Lorries and trucks are expected to be driven along the driveway and under the canopy to access the subject building. Hence, it is considered that the area under the awning shall be of sterile environment and free of fuel loads.

Based on the function and use of the area, and the non-combustible nature of both the canopies themselves and the materials being stored in the warehouse, it is considered that the risk of fire spread to or from the title boundary via the canopies is extremely small.

Further to the above, the perimeter vehicular access road on the reverse side of the title boundary achieves a minimum clear width of 6.0m. This provides the ability for the fire appliance to travel around the entire building.

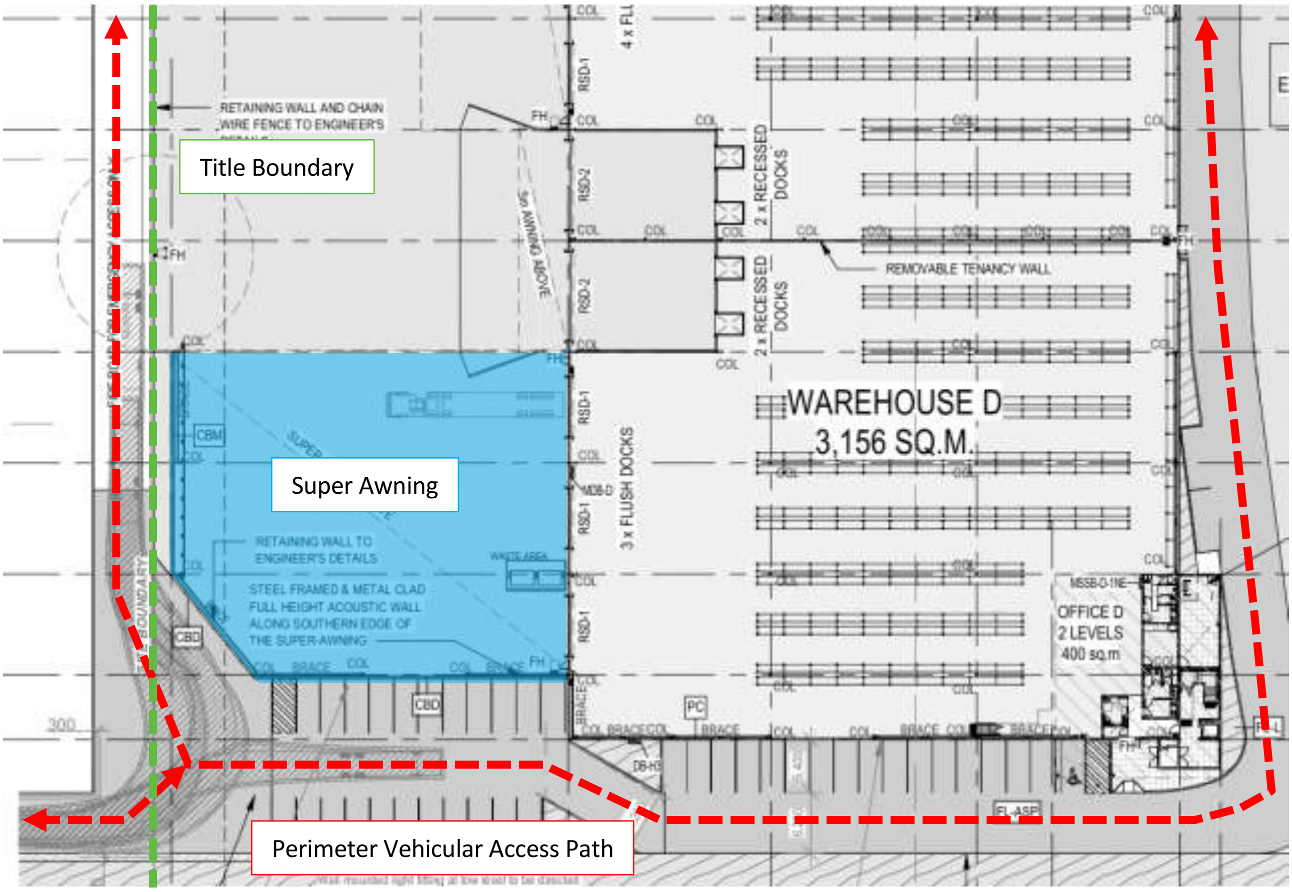


Figure 9.2: Location of super awning and the 6.0m wide perimeter vehicular access road on the reverse side of the title boundary

9.7.1 Sprinkler Effectiveness in Storage Facilities

As noted previously, all areas of the building will have a fully compliant AS2118.1:2017 sprinkler system installed unless otherwise stated. As detailed in Section C3.4 from Volume One of the NCC, sprinklers are deemed to be a reliable method of preventing fire spread. As such, the proposed sprinkler system is expected to control the development and spread of fire within the proposed building as intended under EP1.4 from Volume One of the NCC. Further, the effectiveness of the automatic fire sprinklers in limiting fire spread and growth is supported by statistics and studies undertaken into the effects of automatic fire sprinklers within buildings.

A potential fire within the sprinkler protected storage building is expected to be of reduced intensity as per the sprinkler protection system and building structural elements would be subjected to lesser temperatures and exposure to fire conditions than would structural elements in a DtS compliant non-sprinkler protected building.

Sprinkler protection is expected to provide a reliable and effective means of maintaining tenable conditions for occupants and fire-fighters, structural adequacy, and limiting fire spread within a building and to adjacent building(s). Effective sprinkler activation and operation is also likely to reduce the generation of smoke and maintain low compartment temperatures.

Furthermore, automatic sprinklers have an inherently high reliability. The extensive study by Marryatt (1988) covering the past century of sprinkler protected buildings indicated that sprinkler systems which are soundly managed may have reliability as high as 99.5%. Research findings by Nash and Young (1991) and Bukowski *et al.* (1999) also confirmed the high reliability of sprinkler systems.

With sprinkler activation, it is evident that the effect of sprinklers on a fire is to wet down potential fuel sources, control or suppress the burning process and to cool the resultant smoke layer. It has been cited that the resultant smoke temperatures in a sprinkler-controlled fire are of the order of 100°C -120°C (CIBSE 1997; Sekizawa, 1996). This concept is illustrated in Figure 9.3.

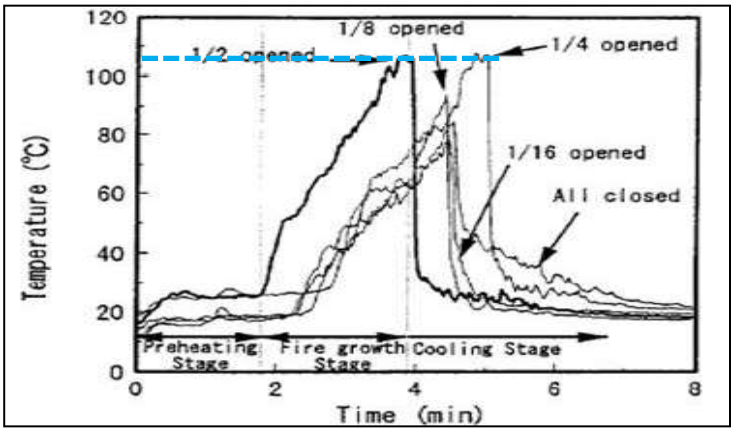


Figure 9.3: Sprinkler controlled room temperatures

Therefore, it is considered that the sprinkler system will reduce the temperatures to the degree necessary whereby occupant and fire fighter life safety are maintained for an extensive period of time.

9.8 Discussion of Assessment Outcomes

The qualitative analysis has demonstrated that the issue of the external canopies has been addressed by the provision of sufficient fire resistance. In particular, the non-combustible construction of the canopies and the specifics of the area's function and use render the likelihood of fire spread via the canopies very low. Based on the rationale presented it is considered that performance requirement CP1 and CP2 from Volume One of the NCC is satisfied.

10. Perimeter Vehicular Access and Open Space Provisions

10.1 Background to the Issue

The subject building is considered to be a Large Isolated Building (LIB) as the building exceeds the maximum volume limitations as permitted in Table C2.2 of Volume One of the NCC. In this regard, the building must be provided with vehicular access and open space provisions as permitted under Clause C2.4 of the NCC from Volume One of the NCC. In this instance, it is proposed to permit open space and vehicular access provisions as per the following:

- The perimeter vehicular access is located more than 18m away from the external wall of the building (Warehouse A, B, C and D) due to the recess docks (i.e. up to 45m); and
- Any perimeter fence gates (and gates forming part of the vehicular access) that are proposed to be locked are required to be fitted with suitable conventional padlocks to enable fire-fighter access with a standard key (i.e. 003 key locks). Alternatively, non-conventional padlocks are permitted provided access keys are provided to Fire & Rescue New South Wales (FRNSW) responding fire station stations.

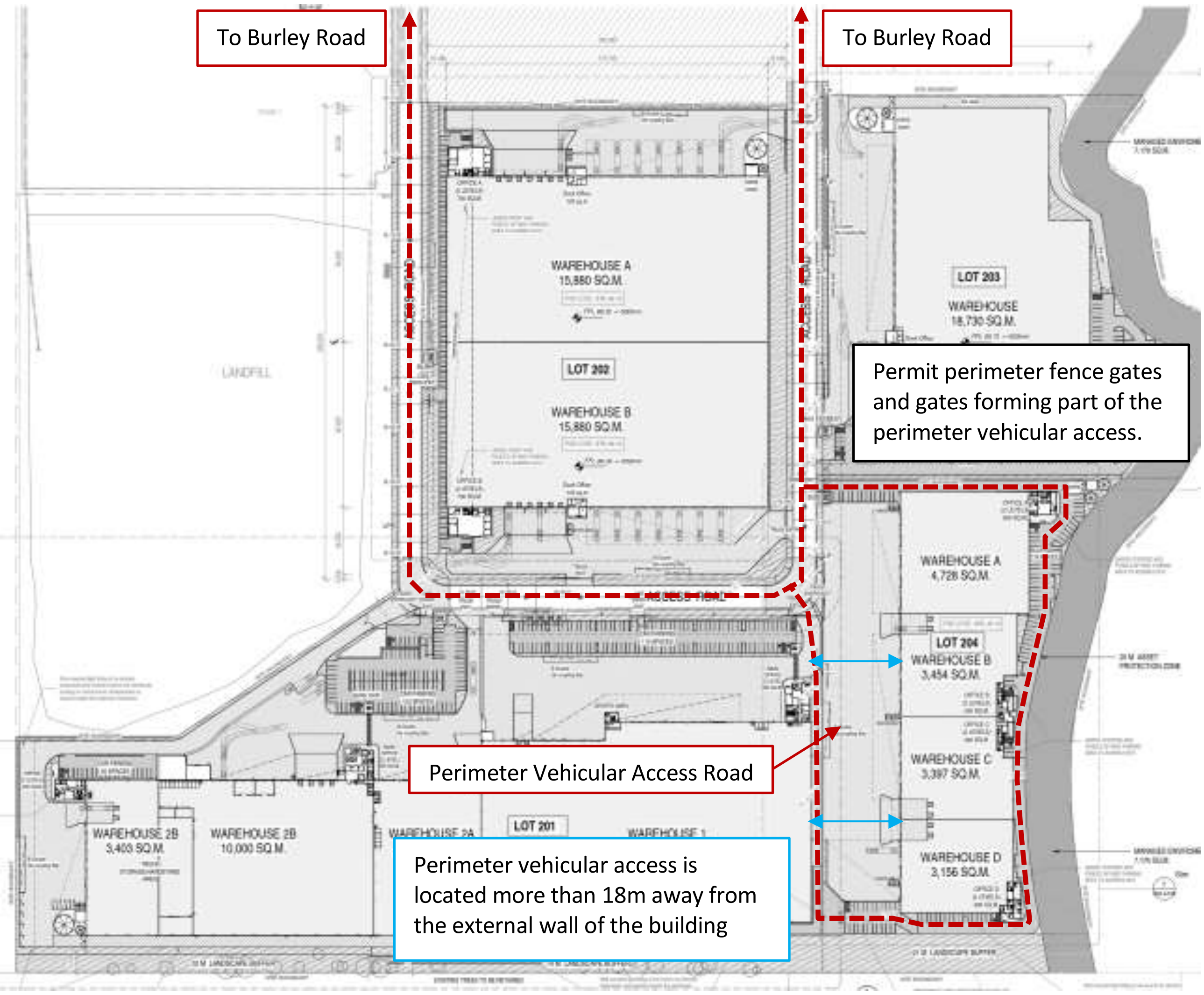


Figure 10.1: Site perimeter vehicular access

10.2 NCC Assessment Methodology

In accordance with the NCC Clause A2.2 *Assessment Methods* the following assessment method has been adopted to determine that the *Building Solution* has met the relevant *Performance Requirement* CP9.

Table 10.1: Method of Analysis

Identified Design Issue	NCC Assessment Method	IFEG Method of Analysis
The following design issues have been identified with respect to the proposed perimeter vehicular access serving the building: • The perimeter vehicular access is located more than 18m away from the external wall of the building (Warehouse A, B, C and D) due to the recess docks; and • Any perimeter fence gates (and gates forming part of the vehicular access) that are proposed to be locked are required to be fitted with suitable conventional padlocks to enable fire-fighter access with a standard key (i.e. 003 key locks). Alternatively, non-conventional padlocks are permitted provided access keys are provided to Fire & Rescue New South Wales (FRNSW) responding fire station stations.	A2.2(2)(b)(ii) such other *Verification Methods* as the *appropriate authority* accepts for determining compliance with the *Performance Requirements*.	A qualitative evaluation has been adopted based on direct consultation with Fire & Rescue NSW (FRNSW).

10.3 Hazard Specific to Open Space & Vehicular Access Provisions

The 'Guide to the NCC' (ABCB, 2019) states that the intent associated with provided perimeter vehicular access and open space provisions is *"To set the minimum requirements for open space around a building and the provision of vehicular access for the Fire Brigade".* It is therefore considered that the main hazards specific to the design issues requiring assessment are:

- The risk of objects or encroachments impeding Fire Brigade activities and thereby endangering the life and safety of occupants and property; and
- A potential fire may be rather significant from one side or part of the building therefore if access to this particular side was unavailable then it may negatively impact Fire Brigade activities; and
- The risk of obstruction on the vehicular access path impeding on vehicular access during Fire Brigade Intervention.

10.4 Hazard Mitigation

The 'Guide to the NCC' (ABCB, 2019) identifies the importance of incorporating continuous perimeter access to the Fire Brigade and the risk associated with Fire Brigade access and fire spread without access. In this regard the following hazard mitigation systems, requirements and features of the design are noted:

- The perimeter access serving the development shall be continuous and comply with the DtS provisions from Volume One of the BCA; and
- The entire building shall be provided with automatic fire sprinkler protection in accordance with AS 2118.1:2017. The sprinkler system shall be as follows:
  - The Class 5 office portion of the subject building is to be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 appropriate to 'Light Hazard' classification; and
  - The Class 7b warehouse portion of the subject building is to be sprinkler protected with the installation of K22 Storage Sprinkler or equivalent incorporating 'fast response' type heads. The activation temperature of Storage sprinkler heads shall be no more than 100°C; and
  - Covered awnings forming part of the Class 7b portion of the subject building shall be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 to 'Ordinary Hazard 3' classification unless otherwise Storage Sprinklers are proposed; and
- The perimeter vehicular access is located more than 18m away from the external wall of the building (Warehouse A, B, C and D) due to the recess docks (i.e. up to 45m); and
- Any perimeter fence gates (and gates forming part of the vehicular access) that are proposed to be locked are required to be fitted with suitable conventional padlocks to enable fire-fighter access with a standard key (i.e. 003 key locks). Alternatively, non-conventional padlocks are permitted provided access keys are provided to Fire & Rescue New South Wales (FRNSW) responding fire station stations; and
- Maintain the perimeter vehicular access paths free of static storage and combustible materials at all times; and
- Fire hydrant system compliant with the relevant Australian Standards unless otherwise detailed herein.

10.5 Methodology

A qualitative methodology has been adopted to address the proposed vehicular access provisions with consideration given towards the effectiveness and efficacy surrounding the following:

- Operational firefighting ability and any potential impacts on operational functions undertaken during firefighting operations;
- Potential firefighter impacts as a direct result of the function and use of the building, likely fire load and potential fire intensity and hazard in association with the active and passive fire mitigation systems;
- Fire appliance and other emergency vehicle access around the entire site including the ability to ensure emergency vehicles do not obstruct appliance manoeuvrability and access around the site.

The assessment methodology has also considered the Standard Operational Guideline's (SOG's) of firefighting personnel which is has been obtained following direct consultation with the FRNSW.

10.6 Acceptance Criteria

The acceptance has been met by demonstrating that the proposed vehicular access and open space provisions are satisfactory to accommodate access to and around the building in order to facilitate fire brigade intervention. The aim is to ensure the efficacy of fire-fighting operations is maintained such that there are no undue impacts on the deployment of safe Standard Operational Guideline's (SOG's).

Overall, the approach demonstrates that the proposed vehicular access allows for fire brigade personnel to undertake their operational procedures without access being unduly impacting on the efficacy of fire-fighting operations.

10.7 Evaluation of Perimeter Vehicular Access and Open Space Provisions

10.7.1 FRNSW Consultation

The FEB has been formally submitted to FRNSW for their review and comment relative to the fire-fighter's requirements with respect to the following:

- The perimeter vehicular access is located more than 18m away from the external wall of the building (Warehouse A, B, C and D) due to the recess docks (i.e. up to 45m); and
- Any perimeter fence gates (and gates forming part of the vehicular access) that are proposed to be locked are required to be fitted with suitable conventional padlocks to enable fire-fighter access with a standard key (i.e. 003 key locks). Alternatively, non-conventional padlocks are permitted provided access keys are provided to Fire & Rescue New South Wales (FRNSW) responding fire station stations.

Furthermore, the FRNSW has provided in-principal support of the above design issues as Appendix J.

10.7.2 Sprinkler Protection

The subject building shall be constructed in accordance with Type C fire resisting construction and is deemed to satisfy the relevant Performance requirements. Based on the expected function & use of the building, building size, potential fire load, intensity and overall fire hazard, the building shall be provided with an automatic sprinkler system in accordance with AS2118.1:2017 unless otherwise identified herein. Sprinkler protection is expected to limit the likelihood of fire development and spread, reducing the likelihood of the following:

- Catastrophic structural collapse; and
- Fire development and spread beyond the building; and
- Untenable conditions for occupant life safety; and
- Untenable conditions for fire-fighters undertaking fire-fighting operations.

Based on the above, it is considered that the FRNSW will have the ability to undertake an offensive fire attack. Based on the reliability and effectiveness of the sprinkler system to control the development and spread of fire, any lightweight or non-fire rated materials used throughout the construction of the building are not likely to significantly contribute to the overall fire load within the building.

10.7.3 Sprinkler Effectiveness in Storage Facilities

As noted previously, all areas of the building will have a fully compliant AS2118.1:2017 sprinkler system installed unless otherwise stated herein. As detailed in Section C3.4 from Volume One of the BCA, sprinklers are deemed to be a reliable method of preventing fire spread. As such, the proposed sprinkler system is expected to control the development and spread of fire within the proposed building as intended under EP1.4 from Volume One of the BCA. Further, the effectiveness of the automatic fire sprinklers in limiting fire spread and growth is supported by statistics and studies undertaken into the effects of automatic fire sprinklers within buildings.

A potential fire within the sprinkler protected storage building is expected to be of reduced intensity as per the sprinkler protection system and building structural elements would be subjected to lesser temperatures and exposure to fire conditions than would structural elements in a DtS compliant non-sprinkler protected building.

Sprinkler protection is expected to provide a reliable and effective means of maintaining tenable conditions for occupants and fire-fighters, structural adequacy, and limiting fire spread within a building and to adjacent building(s). Effective sprinkler activation and operation is also likely to reduce the generation of smoke and maintain low compartment temperatures.

Furthermore, automatic sprinklers have an inherently high reliability. The extensive study by Marryatt (1988) covering the past century of sprinkler protected buildings indicated that sprinkler systems which are soundly managed may have reliability as high as 99.5%. Research findings by Nash and Young (1991) and Bukowski *et al.* (1999) also confirmed the high reliability of sprinkler systems.

With sprinkler activation, it is evident that the effect of sprinklers on a fire is to wet down potential fuel sources, control or suppress the burning process and to cool the resultant smoke layer. It has been cited that the resultant smoke temperatures in a sprinkler-controlled fire are of the order of 100°C -120°C (CIBSE 1997; Sekizawa, 1996). This concept is illustrated in Figure 10.2.

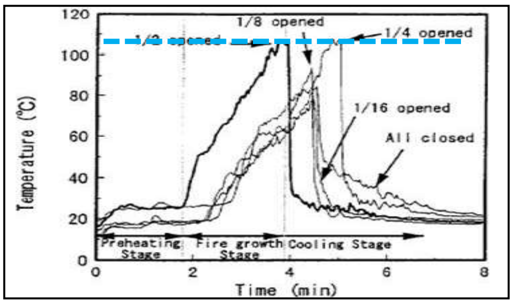


Figure 10.2: Sprinkler controlled room temperatures

Therefore, it is considered that the sprinkler system will reduce compartment temperatures to the degree necessary whereby occupant and fire fighter life safety are maintained for an extensive period of time.

As such, it can be seen that upon activation of a fully compliant and reliable sprinkler system that the structural members are unlikely to be exposed to severe fire development and high temperature conditions that could cause them to lose their strength and fail.

10.7.4 USA (NFPA) Statistical Incident Data

As mentioned previously, studies have shown that fire sprinkler systems operate and control fires in 81% to 99.5% of fire occurrences. The lower reliability estimates of 81.3% as well as some of the higher values of 87.6% appear to reflect significant bias in data in terms of small number of fire incidents and the lack of differentiation between fire sprinklers and other fire suppression systems. It must be noted that the higher reliability of fire sprinklers reported by Marryatt of 99.5% reflect fire sprinkler systems where inspections, testing and maintenance exceeded normal expectations and applies to installations specifically in Australia and New Zealand. The statistical data from the paper titled “US Experience with Sprinklers” indicate that sprinklers with appropriate maintenance are highly effective in reducing the loss of life and limiting fire spread. More recent data studies indicate that the operational reliability of automatic sprinkler systems may be decreasing. However, improvements in the data collection system enable a better evaluation of the data and based upon the August 2005 NFPA report, the operational reliability of sprinkler systems may be as high as 93%.

The sprinkler effectiveness in reducing loss of life, property and containing a fire to the area of fire origin has been documented in the paper titled “US Experience with Sprinklers” (NFPA 2003). The following statistical data is summarised based on data collected during the period of 1989 – 1999.

Table 10.2: Storage facilities – extent of flame damage

Extent of Flame Damage	Storage Facilities - Extent of Flame Damage	
	With Sprinklers	Without Sprinklers
	Fires	Fires
Confined to object of origin	450 (50%)	5,840 (19.9%)
Confined to area of origin	250 (27.8%)	4,150 (14.4%)
Confined to room of origin	60 (6.7%)	1,450 (4.9%)
Confined to fire-rated compartment of origin	10 (1.1%)	180 (0.6%)

Extent of Flame Damage	Storage Facilities - Extent of Flame Damage	
	With Sprinklers	Without Sprinklers
	Fires	Fires
Confined to floor of origin	20 (2.2%)	320 (1.1%)
Confined to structure of origin	90 (10%)	13,200 (45%)
Extended beyond structure of origin	20 (2.2%)	4,190 (14.3%)
Total	**900 (100%)**	**29,330 (100%)**

As can be seen from the above table, despite the reduced number of incidents recorded for sprinkler protected storage facilities, the percentage likelihood of fire confinement to the fire start location is considerably higher when compared to storage premises without sprinkler protection.

Table 10.3: Estimated reduction in 189-1998 civilian deaths per thousand

Property Use	Civilian Deaths per Thousand Fires		
	Without Sprinklers	With Sprinklers	Percentage Reduction
Public Assembly	1.1	0.0	100%
Residential	9.4	2.1	78%
Industrial	1.1	0.0	100%
Manufacturing	2.0	0.8	60%
Storage	**1.0**	**0.0**	**100%**

With reference to the above, civilian fatalities have be reduced by 100% during an entire ten-year period due to the presence of sprinklers within storage facilities.

Table 10.4: Percentage of operating sprinklers

Property Use	Percentage of Operating Sprinklers where Sprinklers were present	
	Percentage of Fires during 1989-1998	Percentage of Fires in 1999
Public Assembly	73.9%	70.2%
Educational	79.6%	76.2%
Offices	80.6%	81.1%
Industrial	85.9%	88.3%
Manufacturing	91.1%	90.7%
Storage	84.0%	84.5%

The table above indicates the percentage of fires that occurred in properties where sprinklers operated. The table suggests percentages to be somewhat lower than sprinkler performance statistics typically cited in older studies, however the percentages are considered to be misleading due to a number of partial installations, as well as structure fires not being large enough to activate an installed sprinkler system.

Furthermore, the graph depicted in Figure 10.3 it is clearly suggested that in terms of effectiveness in mitigating flame spread beyond the room of fire origin sprinklers are approximately 30% more effective than compartmentation arising from fire rated construction in a warehouse/storage building.

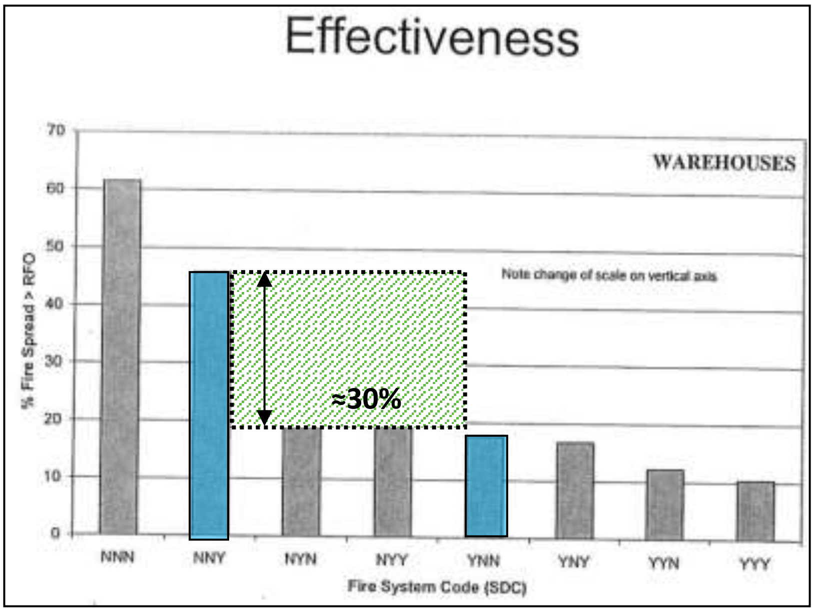


Figure 10.3: System effectiveness in warehouse/storage fires

10.7.4.1 Statistical Analysis – Summary

The statistical data indicates sprinklers are highly effective in reducing the loss of life (and property) during fires. When sprinklers are present, the likelihood of fire development and spread beyond the room of fire origin is considered to be low. With appropriate maintenance, sprinklers have a high reliability of activating and preventing or limiting fire spread. Although sprinkler systems are not completely designed to fully extinguish fires, its ability to effectively limit the development growth and spread provides the attending fire-fighters with the ability to extinguish a decaying fire.

10.7.5 Open Space Provisions

One of the main purposes for a large isolated building to be provided with vehicular access is to enable fire crews to access all parts of the building and furthermore, enable the Fire Brigade to intervene to fight the fire, assist with evacuation and stop the spread of fire to another building (i.e. adjoining property). There are no openings or non-fire rated elements within the external walls that are located within minimum setback distances to a fire sources feature (e.g. title boundary). Therefore, the likelihood of excessive radiant heat flux levels received along the vehicular access locations or title boundaries are deemed to comply with the DtS provisions from Volume One of the NCC.

The open space provision is provided as a fire break between a potential fire within a building and fire appliance situated on the perimeter access road. It is important to note that the perimeter vehicular access road is permitted to be immediately adjacent to a sprinkler protected building. By having a vehicular access road greater than 18m away from the building provides more than adequate fire shielding between a fire within the building and the fire appliance set-up location.

It is also important to highlight that the intent of the vehicular access roadway being located within 18m of the building is to ensure fire crews are located within reasonable proximity to fire hydrants. The subject building is provided with a fire hydrant system commensurate with AS2419.1:2005, with the exception of the following items listed below and as detailed in Section 13.

- Permit the fire hydrant booster assembly to not be within sight of the main entry of the building; and
- Permit fire hydrants without the requirement for fire rated shield panels throughout the entire site; and
- Permit fire hydrants to be located beneath awning structures and furthermore, be designed to achieve external fire hydrant performance;
- Provide additional external 'fall back' hydrant(s) to facilitate operations such that fire-fighters are able to utilise the fire hydrants located beneath the covered awnings (refer to Figure 13.1 for further details). The external 'fall back' fire hydrants are to be located within 60m if the fire hydrants located beneath the covered awnings, be located as close as possible to the perimeter vehicular access location and furthermore are to be design and installed to achieve attack fire hydrant performance; and
- Permit fire hydrants coverage to be calculated based on Clause 3.5.3.3(b) of AS2419.1:2017, where the building parts receiving coverage are within 70m of the external fire hydrants.
- The fire hydrant pump room is deemed to be located internal to the building. Therefore, the requirements for the pump room must strictly be in accordance with Clause 6.4.2 from aS2419.1:2005 with respect to the bounding construction of the pump room enclosure and location of doorways leading to open space.

FRNSW had no objection to the open space requirements (refer to Appendix J).

10.7.6 Vehicular Access Provisions – Main Entry and Other Gates

The FRNSW offered it's in-principal support with respect to the provision for gates to be located within the perimeter vehicular access road. More specifically;

- Any perimeter fence gates (and gates forming part of the vehicular access) that are proposed to be locked are required to be fitted with suitable conventional padlocks to enable fire-fighter access with a standard key (i.e. 003 key locks). Alternatively, non-conventional padlocks are permitted provided access keys are provided to Fire & Rescue New South Wales (FRNSW) responding fire station stations.

FRNSW has provided in-principal support to the above vehicular access requirements (refer to Appendix J).

10.8 Discussion of Assessment Outcomes

The qualitative evaluation has demonstrated that the vehicular access provisions serving the subject site do not present an adverse impact for attending Fire Brigade personnel in the event of an emergency fire situation. Fire crews are provided with continuous vehicular access.

It is also noted that a fully compliant hydrant system (unless identified herein, refer to Section 16) is provided throughout the site. The assessment has demonstrated that an expected fire scenario within the subject warehouse will not have an adverse impact on Fire Brigade intervention activities. The acceptance criterion has been based on the ability for attending fire crews to deploy Standard Operational Guideline's (SOG's) and has been satisfied. Therefore, it is deemed that the proposed design satisfies the Performance Requirement of CP9 from Volume One of the BCA.

11. Egress Provisions & Smoke Hazard Management (Warehouse Portions)

11.1 Background to the Issue

It has been identified that the exit travel distances within the warehouse portion exceed the maximum travel distances as permitted by the prescriptive provisions from Volume One of the NCC. In this instance it is proposed to permit exit travel distances as per the following:

Warehouse A

1. To permit the distance of travel to designated exits of up to 45m in lieu of 40m; and
2. To permit the distance of travel between alternative exits of up to 84m in lieu of 60m.

Warehouse B

3. To permit the distance of travel between alternative exits of up to 66m in lieu of 60m.

Warehouse C

4. To permit the distance of travel between alternative exits of up to 63m in lieu of 60m.

Warehouse D

5. To permit the distance of travel between alternative exits of up to 63m in lieu of 60m.

Furthermore, it is proposed to omit the provision of an automatic smoke exhaust system within the building (including the associated baffles and smoke detectors). In this instance, it is proposed to permit a manually operated smoke clearance system having a smoke clearance capacity of 1 air change per hour.

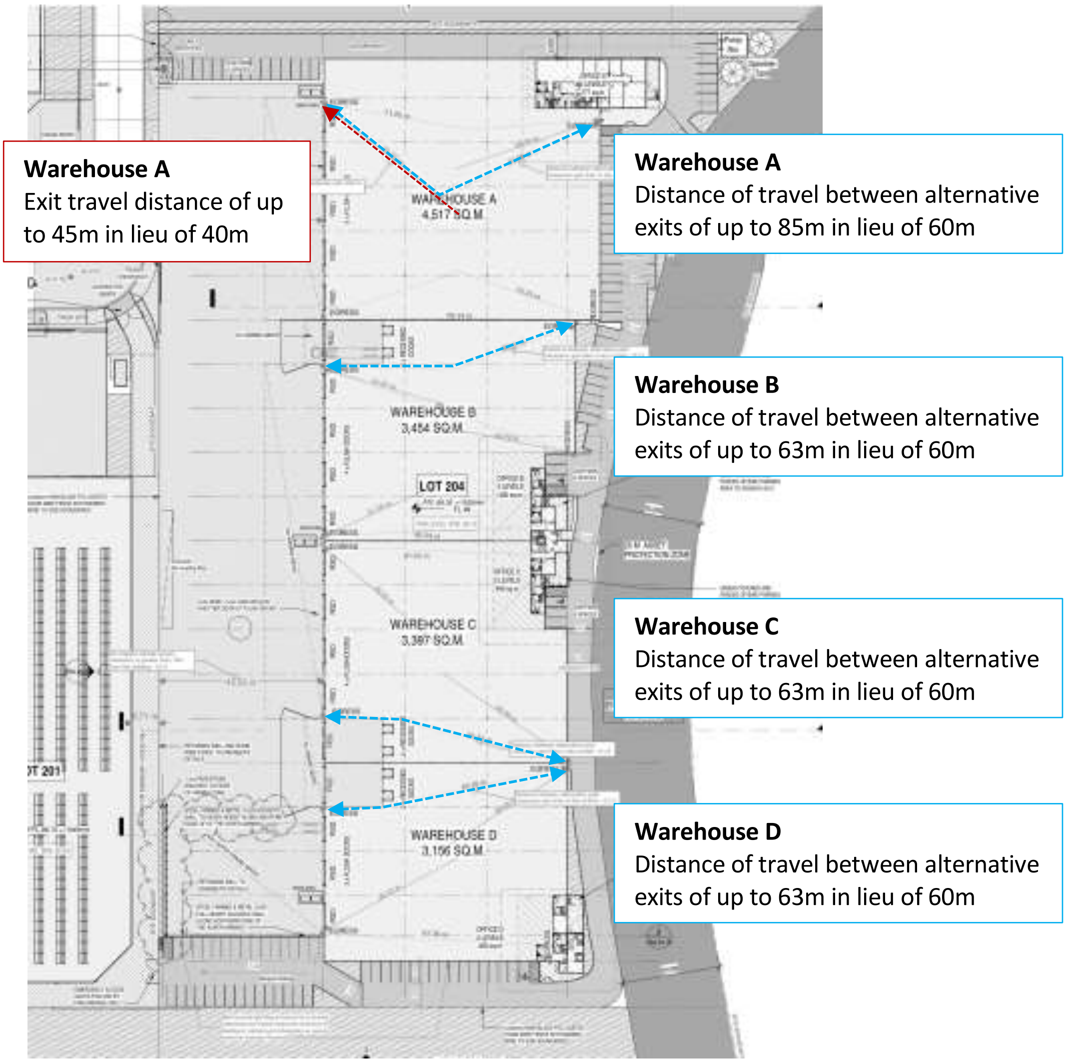


Figure 11.1: Occupant travel distance mark-up

11.2 NCC Assessment Methodology

In accordance with the NCC Clause A2.2 *Assessment Methods* the following assessment method has been adopted to determine that the *Building Solution* has met the relevant *Performance Requirements of DP4 & EP2.2.*

Table 11.1: Method of Analysis

Identified Design Issue	NCC Assessment Method	IFEG Method of Analysis
It has been identified that the exit travel distance to one of the alternative exits and distance between alternative exits within the warehouse portion exceeds the maximum prescribed exit travel distances. More specifically: **Warehouse A** • To permit the distance of travel to designated exits of up to 45m in lieu of 40m; and • To permit the distance of travel between alternative exits of up to 84m in lieu of 60m. **Warehouse B** • To permit the distance of travel between alternative exits of up to 66m in lieu of 60m. **Warehouse C** • To permit the distance of travel between alternative exits of up to 63m in lieu of 60m. **Warehouse D** • To permit the distance of travel between alternative exits of up to 63m in lieu of 60m.	A2.2(2)(b)(ii) such other *Verification Methods* as the *appropriate authority* accepts for determining compliance with the *Performance Requirements*.	A quantitative 'deterministic' & 'absolute' approach whereby an occupant and fire-fighter life safety assessment has been developed in the form of an ASET/RSET timeline analysis.
It is proposed to omit the provision of an automatic smoke exhaust system within the building. In this instance, it is proposed to permit a manually operated smoke clearance system having a smoke clearance capacity of 1 air change per hour per warehouse enclosure.		

The design issues associated with the occupant egress has been evaluated by way of an overall holistic assessment that was developed with consideration of all occupants within the warehouse. The exit travel distance issues have been addressed with consideration to the fire safety systems installed within the building to ensure tenability limits are not breached during the evacuation process or firefighting operations.

Similarly, the design issue associated with the omission of an automatic smoke exhaust system and associated smoke baffle & automatic smoke detection system has been evaluated by way of an overall holistic assessment that has been developed with consideration of all fire safety systems proposed within the building, coupled with the life safety of the occupants and potential attending Fire Brigade personnel.

11.3 Hazard Specific to Egress Provisions

The Guide to the NCC (ABCB, 2019) states that the intent behind providing a maximum travel distance of 40m to reach an exit is *"To maximise the safety of occupants by enabling them to be close enough to an exit to safely evacuate."* With respect to the intent behind providing a maximum travel distance between exits of 60m is "*To* ensure that *if an exit is inaccessible, access to any required alternative exit is available within a reasonable distance* and more specifically *to minimise the need for occupants to travel to far to an exit".*

It is therefore, considered that the main hazards specific to the design issues requiring assessment are:

- Increase in travel time associated with the additional distance of travel; that is time to evacuate will be increased from that of the NCC prescriptive design.
- Increase in potential obstructions within the path of travel to the alternative exit within the path of travel.
- Potential for fire by-products (smoke and toxic gasses) to restrict the path of travel where distance of travel is extended (i.e. potential for tenability limits to be exceeded within the path of travel).
- Increase in travel time associated with the additional distance of travel to an alternative exit after already travelling in the direction to an exit; that is time to evacuate will be increased from that of a prescriptive design.

11.4 Hazard Specific to Smoke Hazard Management

The 'Guide to the NCC' (ABCB, 2019) states that the intent towards providing a smoke hazard management system within the building is "t*o minimise the risks associated with smoke to both the evacuating occupants and the attending fire fighters.* It is therefore considered that the main hazards specific to the issue to be considered in the assessment are:

- The potential for fire by-products (smoke and toxic gasses) to restrict the path of occupant travel (i.e. potential for tenability limits to be exceeded within the path of travel).
- This issue is directly related to occupant evacuation and fire-fighter operation as the smoke hazard management system needs to ensure that conditions are acceptable for both to occur.

11.5 Hazard Mitigation

The 'Guide to NCC' (ABCB, 2019) identifies the hazards as being directly related to the facilitation of occupant evacuation and Fire Brigade intervention activities in the event of an emergency fire situation. In this regard the following hazard mitigation systems, requirements and features of the design are noted:

- The entire building shall be provided with automatic fire sprinkler protection in accordance with AS 2118.1:2017. The sprinkler system shall be as follows:
  - The Class 5 office portion of the subject building is to be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 appropriate to 'Light Hazard' classification; and
  - The Class 7b warehouse portion of the subject building is to be sprinkler protected with the installation of K22 Storage Sprinkler or equivalent incorporating 'fast response' type heads. The activation temperature of Storage sprinkler heads shall be no more than 100°C; and
  - Covered awnings forming part of the Class 7b portion of the subject building shall be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 to 'Ordinary Hazard 3' classification unless otherwise Storage Sprinklers are proposed; and
- A post-incident smoke clearance system shall serve the warehouse portions which shall allow fire crews to vent hot smoke and toxic gases from the warehouses during fire brigade intervention; and
- The occupants within the building will be familiar with their surroundings and will be familiar with the basic internal racking layout (way finding) design contained within the warehouse; and
- The large internal volume spaces provide a natural smoke reservoir for the hot smoke and toxic gases to accumulate allowing additional time for safe occupant evacuation; and
- Exit signs and directional exit signs are to be installed throughout the building in accordance with Clauses E4.5, E4.6 and E4.8 from Volume One of the BCA and AS2293.1:2018 and assessed herein.

11.6 Methodology

The design issues associated with the occupant egress has been evaluated by way of an overall holistic assessment that has been developed with consideration of all occupants from the warehouse. The design issues have been addressed through a deterministic and absolute approach demonstrating occupant life safety for acceptable durations of time. The exit travel distance and distance between alternative exits has been addressed with consideration to the fire safety systems installed within the building to ensure tenability limits are not breached during the evacuation process or firefighting operations.

The methodology and acceptance criteria associated with this deterministic and absolute approach is provided in significant detail within Section 5 of this report. The issue has been addressed through a deterministic and absolute approach to the demonstration of occupant and fire fighter life safety for acceptable durations of time. The methodology and acceptance criteria associated with this deterministic and absolute approach is provided in significant detail within Section 5.6 of this report.

The methodology adopted to address the egress and smoke hazard management provision was quantitatively assessed with consideration to ensuring occupants within the building have the ability to evacuate to a road or open space before being exposed to untenable conditions. Furthermore, the same quantitative analysis has ensured that the omission of a smoke hazard management ensures fire-fighters have the ability to access the building within a timeframe which enables the commencement of water application activities before being exposed to untenable conditions.

11.7 Acceptance Criteria

An ASET/RSET assessment has been undertaken to demonstrate occupant life safety. The factor of safety adopted was in excess of 1.5 for the core scenarios. In this regard, the following criteria has been met:

ASET > 1.5 x RSET

For the ASET/RSET assessment for fire services personnel safety the factor of safety adopted was in excess of 1.5. In this regard, the following criteria has been met:

ASET > 1.5 x FBIM (commencement of water application)

Redundancy and factors of safety are two (2) concepts that are considered concurrently. The redundancies in the design has been considered in the analysis to ensure suitable levels of conservatism are achieved. The factors of safety adopted for sensitivity studies where system failure scenarios are adopted have been reduced to 1.0. In this regard, the following criteria has been met:

ASET > 1.0 x RSET

11.8 Evaluation of Occupant Egress and Smoke Hazard Management System Provisions

11.8.1 General

The issue pertaining to the safe egress of the building occupants relates to the distance to the nearest available exit and the risk of the travel path becoming untenable. Exit travel time is a function of distance. Therefore, in areas where an occupant receives early signs of a fire either visual or from olfactory cues they would be expected to react prompt and initiate evacuation. Conversely in areas where the occupants are remote from the area of fire origin (AFO) greater time may be required for the occupants to assess if the threat is real and evacuation of the building is required.

11.8.2 Occupant Life Safety

As detailed in Section 8 of this report, the outcomes of the Life Safety Analysis have demonstrated that occupants are able to safely evacuate the warehouse prior to untenable conditions occurring. The fire and smoke modelling has demonstrated that tenable conditions have been provided within the warehouses with adequate time provided for occupants to safely evacuate the building. The warehouses are afforded with multiple exit locations that are evenly distributed around the perimeter of the building. With multiple exits the occupants are able to access the most appropriate practicable path to safely evacuate the building and in the event that one exit is untenable there is always an option for an alternative exit in the near vicinity. Therefore, the factor of safety for both core and sensitivity studies have been met, Appendix F represents the smoke conditions within the warehouses. These results have been provided since it's the core fire scenario for the ASET/RSET Analysis.

It must be noted that the IR method where occupants in close proximity to the fire would react and initiate evacuation almost immediately as discussed in Section 8.2.2 would potentially result in faster overall evacuation time for the zone of fire origin. In this analysis the time taken for all occupants within all areas of the building to evacuate has been taken as the RSET.

The egress simulations have included multiple egress scenario simulations where exits were blocked assumed to be unavailable ensuring adequate redundancy was afforded in the assessment process. It is reiterated that in all events the established acceptance criteria has been satisfied with an adopted factor of safety. The risk associated with a potential fire has also been shown to be acceptable and the occupants are able to safely evacuate from the subject building.

The staff members are considered to be familiar with the building environment in which they work and hence have an in depth understanding of the building layout and more specifically an understanding of the location of exits. It is expected that the staff would be trained in the warehouse's emergency procedures and also in a position to provide an initial attack on a fire with fire hose reels provided within the building. In any event it is expected that staff would be aware of the nearest exit locations and be well versed in assisting any building occupants to the available exits. Upon activation of the BOWS permanent and trained staff within the building would be expected to initiate the emergency evacuation procedures. It must be noted that the ASET/RSET assessment also assumed greater occupant numbers than those expected.

It should be noted that the occupants within office portions of each warehouse are able to exit to an open space via the individual office portions without entering the warehouse.

Visitors to the building may not be aware of emergency procedures however they would have a degree of familiarity of the exit in which they entered the building. Visitors would potentially comprise persons from all gender and age groups with varying levels of physical and mental ability. It is likely that visitors would be able to reach an exit, as staff would be able and expected to assist any visitors in the event that evacuation from the building was required. Essentially all of the building occupants are expected to receive a warning of a fire, either visual or transmitted by the BOWS due to the activation of the automatic fire sprinkler system in a time which allows for safe evacuation.

11.8.2.1 Occupant Life Safety Analysis Outcomes

The level of life safety afforded to the building occupants based on the proposed egress design within the subject building has been supported by FDS modelling and occupant evacuation analysis as evidence in the ASET/RSET life safety analysis detailed in Section 8. The ASET/RSET analysis included the following:

- Total of four (4) fire scenarios have been conducted to determine occupant tenability within the warehouse portions; and
- Total of six (6) evacuation scenarios have been conducted to determine evacuation time within the warehouse portions.

The life safety assessment (ASET/RSET) outcomes captured in Section 8 of this FSER have been analysed and summarised in Table 8.7. The acceptance criteria in terms of life safety margins as detailed have been satisfied. The life safety analysis has demonstrated that occupants are provided with sufficient time to evacuate prior to the smoke layer to descend below 2.1m above the finished floor level.

From the analysis documented in Section 8, the indication of the life safety of the occupants has been obtained by comparison of the ASET and RSET values for the scenarios examined. More specifically the comprehensive ASET/RSET Timeline analysis conducted, as summarised in Table 8.7, has demonstrated that the proposed egress provisions afford building occupants with adequate life safety margins.

The fire and evacuation analysis satisfied the acceptance criteria nominated in Section 5.6. The following criteria have been satisfied with regard to the core fire scenario:

ASET > 1.5 x RSET **Satisfied**

The fire and evacuation analysis satisfied the acceptance criteria nominated in Section 5.6. The following criteria have been satisfied with regard to the *sensitivity* fire scenario:

ASET > 1.0 x RSET **Satisfied**

Similarly, fire scenarios where fire/smoke modelling was conducted, the time required for fire services personnel to conduct intervention activities thus satisfying the acceptance criteria nominated in Section 5.6. The following criteria have been satisfied with regard to the core fire scenarios:

ASET > 1.5 x FBI **Satisfied**

In summary and with consideration of the achieved levels of occupant life safety it is deemed that occupant life safety within the storage warehouse meets an accord with the Performance Requirements DP4 and EP2.2 in regard to occupant life safety.

11.8.3 Fire Brigade Intervention and Operations

The intent towards quantifying Fire Brigade arrival time and intervention time in this instance has been to determine whether the alternative solution is satisfactory (to the degree necessary) to ensure that the attending fire fighters are provided with a ‘safe’ entry point to undertake fire-fighting activities.

The approximate Fire Brigade arrival time for intervention activities has been estimated and assessed whereby Fire Brigade arrival and/or fire-fighting operations Section 6 and as summarised below.

- From fire initiation the cumulative time taken for the closest & second closest fire appliances to reach the fire scene (kerb side) are as follows:
  - Closest (Huntingwood Fire Station): **1708 seconds** or approximately 28.5 minutes;
  - Second Closest (Bonnyrigg Heights Fire Station): **1888 seconds** or approximately 31.5 minutes;
- Having arrived at the fire scene (kerb side), the cumulative time taken for fire crews to gain entry, gather information, assess the situation and set-up water supplies ready for the commencement of water control/extinguishment activities is an additional **641 seconds** or approximately 10.5 minutes;
- From fire initiation to the commencement of water control/extinguishment activities the cumulative time take for the closest & second closest responding fire stations is as follows:
  - Closest (Huntingwood Fire Station): **2349 seconds** or approximately 39 minutes;
  - Second Closest (Bonnyrigg Heights Fire Station): **2529 seconds** or approximately 42 minutes

In line with the AFAC FBIM Model Manuel (Version 3.0, dated 14/04/2020) the total time taken for fire brigade intervention is based upon the second closest fire station. In this regard, attending fire crews from Bonnyrigg Heights Fire Station are expected to conduct water control/extinguishment activities within **2529 seconds** or approximately 42 minutes.

Once the fire brigade arrives of site, they can determine an appropriate place to undertake their operations given the site providing direct access to the all the buildings on site directly from street level. Hence, it is unlikely that the identified travel distance within the warehouse will have an adverse impact towards firefighting operations.

With reference to the fire fighter acceptance criteria and the established fire and smoke modelling outcomes, it is considered that the conditions within the zone of fire origin is not likely to compromise the life safety of the attending fire fighters. The fire and smoke modelling outcomes have demonstrated that the temperature's within the Warehouse is not likely to exceed temperature levels greater than 100°C for fire fighters to undertaken fire intervention activities (Routine conditions) for the duration greater than 2700 seconds.

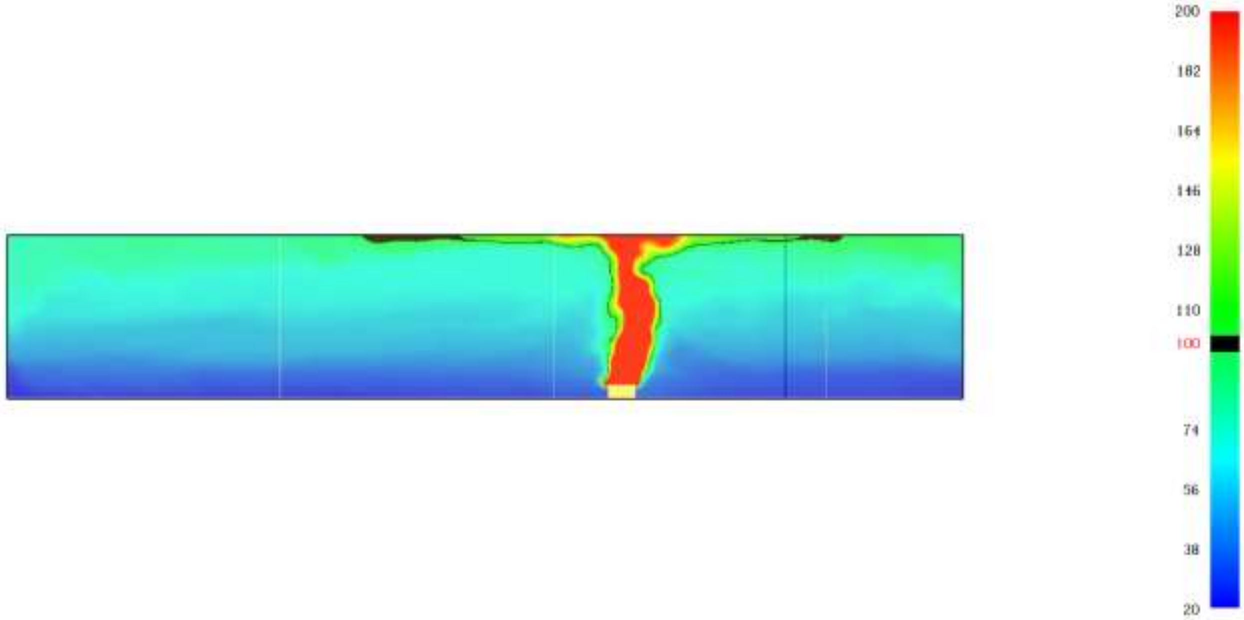


Figure 11.2: Temperature slice files denoting the smoke layer temperature within the warehouse (Sectional view) – HP01C_8.6WA – 2700 seconds

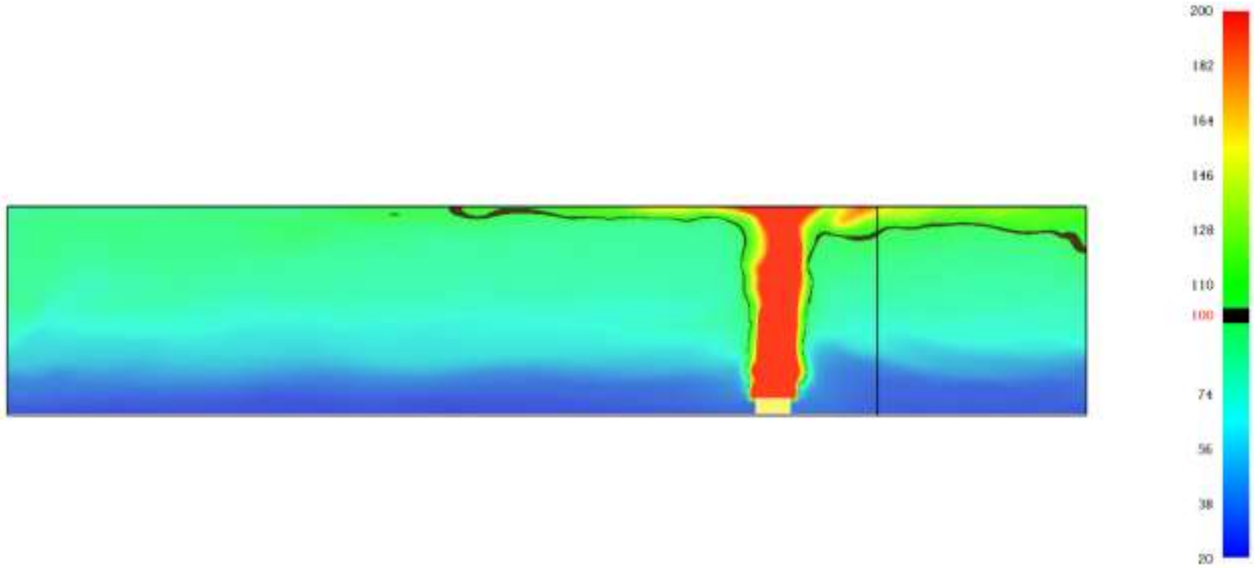


Figure 11.3: Temperature slice files denoting the smoke layer temperature within the warehouse (Sectional view) – HP03C_8.6WD – 2700 seconds

Therefore, with consideration of the achieved levels of fire fighter tenability it is deemed that fire fighters will be able to undertake their standard operational procedures within the warehouse and that the design is deemed to meet an accord with the Performance Requirements DP4 and EP2.2 in regard to fire brigade intervention.

11.9 Assessment Outcomes

The risk to the occupants' life safety and the attending Fire Brigade due to the identified design issues is low based on the quantitative and qualitative analysis undertaken. Therefore, the design issues pertaining to the exit travel distance issues and the omission of the smoke hazard management system within the subject warehouses do not introduce an increased risk to life safety for the evacuating building occupants. Therefore, the building design and Performance Solution is considered to meet the relevant performance. Furthermore, with consideration of the achieved levels of fire fighter tenability it is deemed that fire fighters will be able to undertake their standard operational procedures within the building, as such the subject building is deemed to meet the relevant performance requirements.

As such the design issues associated with the identified exit travel distance issues and the omission of an automatic smoke exhaust system within the subject warehouses is deemed to meet an accord with the relevant Performance Requirements DP4 and EP2.2 from Volume One of the NCC. This conclusion is contingent on the recommendations in Section 16 being implemented into the design.

12. Egress Provisions (Office Portion)

12.1 Background to the Issue

It has been identified that the exit travel distance to an exit within the Level 1 office portions exceeds the maximum prescribed travel distance. More specifically:

Office A

- To permit the distance of travel to designated exits of up to 30m in lieu of 20m.

Office B

- To permit the distance of travel to designated exits of up to 30m in lieu of 20m.

Office

- To permit the distance of travel to designated exits of up to 30m in lieu of 20m.

12.2 Assessment Methodology

In accordance with the BCA Clause A2.2 *Assessment Methods* the following assessment method has been adopted to determine that the *Performance Solution* meets the relevant *Performance Requirements DP4 & EP2.2*.

Table 12.1: Methods of Analysis

Identified Design Issue	BCA Assessment Method	IFEG Method of Analysis
It has been identified that the exit travel distance to an exit within the <u>office portion</u> exceeds the maximum prescribed exit travel distances. More specifically: **Office A** • To permit the distance of travel to designated exits of up to 30m in lieu of 20m. **Office B** • To permit the distance of travel to designated exits of up to 30m in lieu of 20m. **Office C** • To permit the distance of travel to designated exits of up to 30m in lieu of 20m.	A2.2(2)(d) Comparison to the DtS provisions of the BCA.	A qualitative risk approach demonstrating that the performance solution satisfies the relevant Performance Requirement.

12.3 Hazard Specific to Egress Provisions

The Guide to the BCA (ABCB, 2019) states that the intent associated with prescribing a maximum distance of travel as being *"To maximum the safety of occupants by enabling them to be close enough to a point of choice/exit to safely evacuate".* It is therefore, considered that the main hazards specific to the issue to be considered in the assessment are:

- Increase in travel time associated with the additional distance of travel, that is time to evacuate will be increased from that of the BCA prescriptive design.
- Increase in potential obstructions within the path of travel.
- Potential for fire by-products (smoke and toxic gases) to restrict the path of travel where the travel distances are extended (i.e. potential for tenability limits to be exceeded within the path of travel).

12.4 Hazard Mitigation to Egress Provisions

The Guide to BCA (ABCB, 2019) identifies the hazards as being directly related to the facilitation of occupant evacuation in the event of an emergency fire situation. In this regard, the following is noted:

- The Class 5 office portion of the subject building is to be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 appropriate to 'Light Hazard' classification; and
- The Building Occupant Warning System (BOWS) shall actuate upon activation of the automatic sprinkler system and/or smoke detection system. The BOWS shall initiate a General Fire Alarm (GFA) throughout the building; and
- Installations activating the BOWS shall also be connected to a fire alarm monitoring system connected to a fire station or fire station despatch centre in accordance with AS1670.3:2018; and
- Smoke detection shall be provided within the office portion only in accordance with Specification E2.2b and AS1670.1:2018 designed and installed on a spacing of no more than 15m x 15m which shall activate the BOWS throughout; and

- Each enclosure within the office portion shall be provided with no less than one (1) detector. This requirement does not apply to enclosures which contain a shower; and
- Highly trained permanent staff that are aware of the emergency procedures; and
- Exits are clearly visible with appropriate emergency lighting and exit signage to ensure adequate way finding and visibility during evacuation.

12.5 Methodology

The issue pertaining to the distance of travel to an exit has been assessed with respect to the hazards and the potential impact imposed to the occupants. Furthermore, a quantitative "comparative" assessment has been undertaken to consider the fire safety systems (detection and alarm system) to reduce the time to detection, thus occupant notification time which has been compared to the overall evacuation time to that of a design which complies with the DtS provisions.

12.6 Acceptance Criteria

The basic objective and intent of this analysis pertains to the life safety of the evacuating occupants. Thus, the primary acceptance criterion has been met by demonstrating that the proposed fire safety measures and egress provisions associated with the identified office area achieve a level of occupant life safety that meets the relevant Performance Requirements from Volume One of the BCA.

The acceptance criterion has been met by demonstrating that the Required Safe Egress Time (RSET) of the proposed design is at least equivalent to the Required Safety Egress Time of a prescriptive design. In summary the following has been demonstrated:

$$\text{RSET}_{\text{Proposed Building Solution}} \leq \text{RSET}_{\text{BCA-DtS}}$$

12.7 Assessment of Egress Provisions

12.7.1 Overall Evacuation Time (RSET)

In order to undertake this timeline analysis, the emergency evacuation process of building occupants has been addressed. In a fire emergency the response and resultant evacuation has been commonly recognised as comprising three major components. These are:

- Detection Time phase
- Pre-movement phase
- Movement Time phase

Of these three components, the travel time of the occupants to a place of safety is generally the most predictable and typically is the smallest time involved. The alarm activation and cue recognition (i.e. detection) coupled with the pre-movement phases can extend over several minutes of elapsed time. Figure 12.1 depicts a schematic representation of an occupant evacuation timeline analysis.

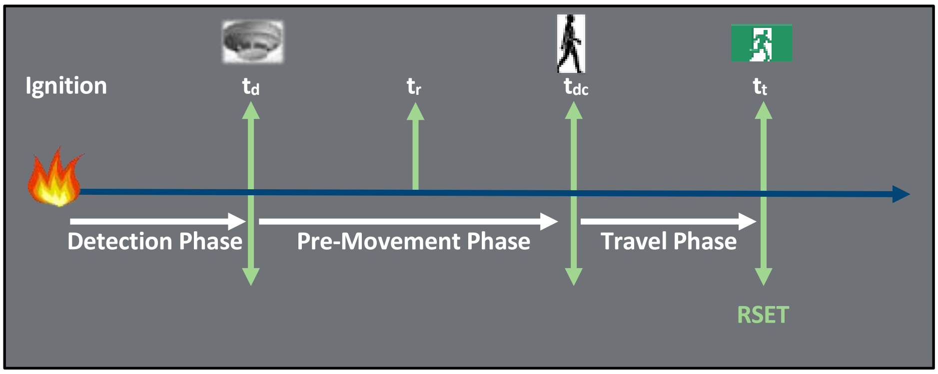


Figure 12.1: 'RSET' Timeline Analysis

As there are no differences between the pre-movement phase of the evacuation process with regards to a DtS compliant design and proposed alternative design comparison, this component need not be addressed in the comparative analysis.

12.7.2 Determining the Detection Time (Performance Solution)

The time for building occupants to detect a fire within the proposed building has been based on automatic smoke detection, while in a DtS building fire would be detected by sprinkler activation. The adoption of automatic smoke detection shall compensate for the additional travel time. Horizontal travel times are assumed to be 0.8m/s (Tubbs, J., Meacham, B., (2007)).

To validate and quantify the approximate time of alarm activation an "in-house" spread sheet calculation has been undertaken.

When the plume above a fire reaches a ceiling, a horizontal jet is formed. To determine the fire detector activation time, Alpert's Correlation has been used to determine the activation time based on the lumped mass heat transfer equation which estimates the hot gases spreading across the ceiling. The fire detection system and estimation of the activation time is based on the methodology prescribed by the IFEG (ABCB, 2005).

Therefore, for the basis of this assessment, the detection time has been based on the time for the proposed detection system to activate. The detection activation time has been based on the worst credible scenario which assumes the following input parameters:

- Fire location: Level 1 Office B (representative of other office levels)
- Distance between fire and detector: 10.6m (based on a 15m x 15m grid spacing)
- Detector height: 2.7m (Ceiling height)
- Smoke Detector activation temperature: 33°C (refer to Heskestad, 1999)
- Smoke Detector RTI: $10m^{0.5}s^{0.5}$ (refer to Evans, 1984)
- Fire growth rate: Medium t^2 fire (CIBSE Guide E, 2010)

Alpert's correlation has been conducted to calculate the smoke detector activation time. The result detailed in Figure 12.2 calculates a detection time of **145 seconds**.

scientific fire services

Alpert's Correlation

Required Inputs		
Ambient Temperature, T =	20	(°C)
Fire Growth Rate =	Medium	
Time Step Interval =	20	(s)
Radial Distance of the Detector from the Fire, r =	10.60	(m)
The Height of the Ceiling above the fire, H =	2.7	(m)
The Response Time Index of the Detector, RTI =	10	$(m^{1/2}s^{1/2})$
Smoke/Sprinkler Density of Discharge =	5	mm / min
Detector Activation Temperature =	33	(°C)
Calculated Quantites at Detector Activation		
The Gas Temperature at Detector Activation, T =	35.52	(°C)
HRR at Detector Activation =	230.40	(kW)
The Gas Velocity, U =	0.27	(m/s)
Time at Detector Activation =	145	(s)
Time to Reach 10% of peak HRR =	831	(s)
Ratio, r / H =	3.93	

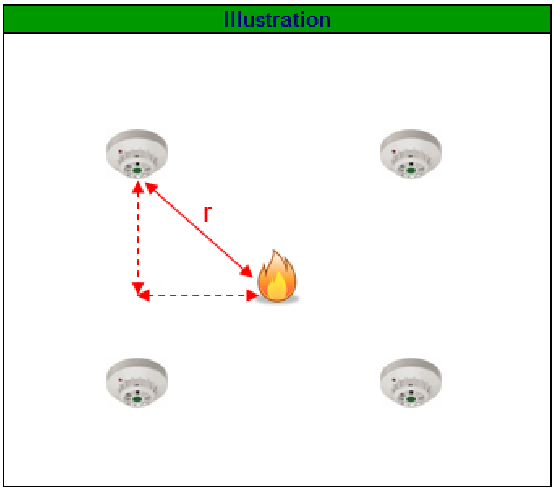


Figure 12.2: Detector activation time within Level 1 portion

12.7.3 Determining the Detection Time (DtS Building Solution)

The DtS building solution would result in the detection time being determined by the activation of the required sprinkler system. Therefore, for the basis of this assessment, the detection time has been based on the time for the proposed sprinkler system to activate. The activation time has been based on the worst credible scenario which assumes the following input parameters:

- Fire location: Level 1 Office B (representative of other office levels)
- Distance between fire and detector: 2.5m
- Detector height: 2.7m (Ceiling height)
- Activation temperature: 68°C (Light Hazard Sprinkler classification - Fast Response Heads)
- RTI: $50m^{0.5}s^{0.5}$ (Light Hazard Sprinkler classification - Fast Response Heads)
- Fire growth rate: Medium t^2 fire (CIBSE Guide E, 2010)

Alpert's correlation has been conducted to calculate the sprinkler activation time. The result detailed in calculates an activation time of **209 seconds**.

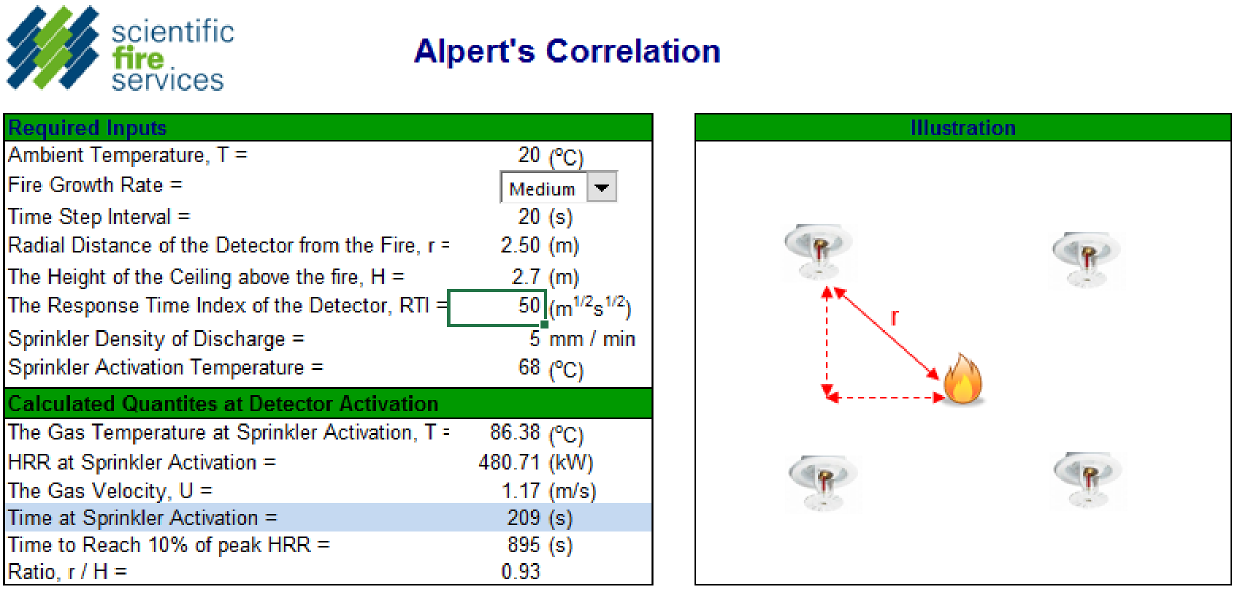


Figure 12.3: Sprinkler activation time within Level 1 portion

12.7.4 Determining the Movement Time to Point of Choice

The travel time during an evacuation process is governed by the movement speed of occupants or queuing at potential bottlenecks such as at an exit or entrance to a fire isolated stair in the subject building. Horizontal travel times are assumed to be 0.8m/s (Tubbs, J., Meacham, B., (2007)).

With a maximum travel distance to a point of choice of 30m, the time for the furthermost occupant to reach this point would be in the order of 38 seconds. Under this condition the additional travel distance of up to 10m is considered to introduce a minor delay of approximately 13 seconds beyond those applicable in any BCA deemed to satisfy compliant design.

12.7.5 RSET Comparison

The evacuation times associated with the proposed performance solution and a DtS building solution are detailed in Table 12.2.

Table 12.2: RSET vs. RSET

Scenario	Detection (s)	Pre-Movement (s)	Movement (s)	RSET (s)	Difference / Safety Margin (s)	$RSET_{PS} \leq RSET_{BCA}$	Acceptance Criteria Met
Distance to a single exit							
DtS building solution (20m)	209	Equivalent	25	234	51	183 ≤ 234	YES
Proposed performance solution (30m)	145	Equivalent	38	183			

12.8 Discussion of Assessment Outcomes

Based upon the quantitative assessment above, it can be concluded that the provision of a detection and alarm system provides occupants with a notification time above and beyond an equivalent DtS building design resulting in an overall improved evacuation time. The extended travel distance to an exit within the Level 1 portions of Office A, B and C for the proposed design is considered to be at least equivalent to a similar DtS-compliant building design. Therefore, the proposed design is deemed to meet the performance requirements DP4 and EP2.2 of the BCA. This conclusion is contingent on the recommendations in Section 16 being implemented into the design.

13. Fire Hydrants

13.1 Background to the Issue

The fire hydrant system shall be design and installed in accordance with AS2419.1:2005 with the exception of the following:

- Permit the fire hydrant booster assembly to not be within sight of the main entry of the building; and
- Permit fire hydrants without the requirement for fire rated shield panels throughout the entire site; and
- Permit fire hydrants to be located beneath awning structures and furthermore, be designed to achieve external fire hydrant performance;
- Provide additional external 'fall back' hydrant(s) to facilitate operations such that fire-fighters are able to utilise the fire hydrants located beneath the covered awnings (refer to Figure 13.1 for further details). The external 'fall back' fire hydrants are to be located within 60m if the fire hydrants located beneath the covered awnings, be located as close as possible to the perimeter vehicular access location and furthermore are to be design and installed to achieve attack fire hydrant performance; and
- Permit fire hydrants coverage to be calculated based on Clause 3.5.3.3(b) of AS2419.1:2017, where the building parts receiving coverage are within 70m of the external fire hydrants.

Figure 13.1: Fire Hydrants (Indicative racking only)

13.2 NCC Assessment Method

In accordance with the NCC Clause A2.2 *Assessment Methods* the following assessment method has been adopted to determine whether the *Building Solution* has met the relevant *Performance Requirements of EP1.3.*

Table 13.1: Method of Analysis

Identified Design Issue	NCC Assessment Method	IFEG Method of Analysis
Fire hydrants are to be located and installed in accordance with NCC Clause E1.3 and AS2419.1:2005 with the exception of the following: • Permit the fire hydrant booster assembly to not be within sight of the main entry of the building; and • Permit fire hydrants without the requirement for fire rated shield panels throughout the entire site; and • Permit fire hydrants to be located beneath awning structures and furthermore, be designed to achieve external fire hydrant performance; • Provide additional external 'fall back' hydrant(s) to facilitate operations such that fire-fighters are able to utilise the fire hydrants located beneath the covered awnings (refer to Figure 13.1 for further details). The external 'fall back' fire hydrants are to be located within 60m if the fire hydrants located beneath the covered awnings, be located as close as possible to the perimeter vehicular access location and furthermore are to be design and installed to achieve attack fire hydrant performance; and • Permit fire hydrants coverage to be calculated based on Clause 3.5.3.3(b) of AS2419.1:2017, where the building parts receiving coverage are within 70m of the external fire hydrants.	A2.2(2)(b)(ii) such other *Verification Methods* as the *appropriate authority* accepts for determining compliance with the *Performance Requirements*.	A qualitative approach whereby the performance of the fire-fighting equipment has been evaluated in direct consultation with Fire & Rescue NSW (FRNSW).

13.3 Hazard Specific to Fire Hydrants

The Guide to the NCC (ABCB, 2019) identifies the potential for fire-fighting personnel to encounter unsafe conditions during Fire Brigade Intervention. In this regard the following hazard mitigation systems. Fire hydrant systems are required to:

- Enable fire crews to undertake search and rescue operations; and
- Enable fire crews to perform fire control activities which including minimising fire spread within a building and to/from adjacent properties/compartments; and
- Undertake fire extinguishment activities and salvage operations.

Fire water and fire hydrant equipment is considered to not only be a means of fire control and suppression however also a means of providing fire-fighting personnel with protection during operations. It is therefore considered that the main hazard associated with the identified design issue relates to:

- Fire crews experiencing delays in accessing the fire seat should it be located within the highlighted areas not achieving fire hydrant coverage; and
- Potential for fire-fighting crews to experience untenable conditions due to potential delays in accessing the location of fire.

13.4 Hazard Mitigation

The 'Guide to the NCC' (ABCB, 2019) identifies the hazards as being directly related to the facilitation of FRNSW being able to undertake Standard Operational Guideline's (SOG's) and intervention activities. In this regard the following hazard mitigation systems, requirements and features of the design are noted:

- The subject building shall be provided with an automatic sprinkler system in that is designed to suppress a fire. The outcome of effective fire sprinkler suppression system operation is to mitigate smoke production through suppression. The propagation of smoke is significantly reduced after sprinkler head activation; and
- Fire hydrant system shall be designed and installed in accordance with the Clause E1.3 from Volume One of the NCC and AS2419.1:2005 unless otherwise detailed herein:
  - Permit the fire hydrant booster assembly to not be within sight of the main entry of the building; and
  - Permit fire hydrants without the requirement for fire rated shield panels throughout the entire site; and
  - Permit fire hydrants to be located beneath awning structures and furthermore, be designed to achieve external fire hydrant performance;
  - Provide additional external 'fall back' hydrant(s) to facilitate operations such that fire-fighters are able to utilise the fire hydrants located beneath the covered awnings (refer to Figure 13.1 further details). The external 'fall back' fire hydrants are to be located within 60m if the fire hydrants located beneath the covered awnings, be

located as close as possible to the perimeter vehicular access location and furthermore are to be design and installed to achieve attack fire hydrant performance; and
- Permit fire hydrants coverage to be calculated based on Clause 3.5.3.3(b) of AS2419.1:2017, where the building parts receiving coverage are within 70m of the external fire hydrants.

- Each fire hydrant outlet shall be provided with a localised block plan (A3 minimum & weather fade resistant) to pictorially and numerically illustrate the next available alternative hydrant outlets; and
- The fire hydrants in the proposed fire hydrant system are to be accessible for use by Fire & Rescue NSW (i.e. clear paths of travel); and
- The fire hydrant pump room is deemed to be located internal to the building. Therefore, the requirements for the pump room must strictly be in accordance with Clause 6.4.2 from aS2419.1:2005 with respect to the bounding construction of the pump room enclosure and location of doorways leading to open space; and
- All on-site fire hydrants are to be fitted with Storz hose couplings which comply with Clause 7.1 of AS2419.1:2005. This clause states in part "hose couples shall be compatible with those used by the fire brigade serving the area". Storz hermaphrodite fire hose couplings must be fitted to all fire hydrants and the fire hydrant booster assembly connections as required by Appendix E of AS2419.1:2005. The Storz fittings must be manufactured to DIN 14303, aluminium alloy delivery couplings, in accordance with Appendix A of AS2419.2-1994. Blank caps must be provided in accordance with Clause 2.8 of AS2419.2-1994; and
- Block plans are to be provided at the fire hydrant booster assembly in accordance with Section 7.11 of AS2419.1:2005 and any additional requirements specified by the FRNSW. In addition to the required information, the plans are also to denote the vehicular perimeter access provision.

13.5 Methodology

The evaluation of the performance design solution relative to the fire hydrant system has been based on a qualitative and quantitative assessment.

A qualitative assessment is considered appropriate (as the appropriate authority accepts for determining compliance with the relevant Performance Requirement) which aims to provide compliance with the relevant Performance Requirements of the NCC by providing fire safety protective and mitigation measures for the performance solution. The design issue pertaining to the fire hydrant installation has been assessed with respect to the hazards and the potential impact imposed towards the attending fire brigade personnel.

Consultation with Fire & Rescue NSW (FRNSW) has been undertaken to assess the impact of fire crews and their ability to safely access the subject hydrants whilst undertaking Standard Operational Guideline's (SOG's).

13.6 Acceptance Criteria

The basic objective and intent of the analysis shall pertain to fire-fighter life safety. Therefore, the primary acceptance criterion has been met by demonstrating that the proposed hydrant design and layout maintains efficacy for fire-fighting operations and the deployment of safe Standard Operational Guideline's (SOG's).

13.7 Evaluation of Fire Hydrant

13.7.1 Fire Rescue New South Wales (FRNSW) Consultation

The FEB has been formally submitted to FRNSW for their review and comment relative to the fire hydrant system. It is considered that this design will allow the attending fire fighters to undertake an attack on a potential fire to the degree necessary and will not impede their ability to undertake standard operation procedure. As such, the FRNSW had no objection to the following:

- Permit the fire hydrant booster assembly to not be within sight of the main entry of the building; and
- Permit fire hydrants without the requirement for fire rated shield panels throughout the entire site; and
- Permit fire hydrants to be located beneath awning structures and furthermore, be designed to achieve external fire hydrant performance;
- Provide additional external 'fall back' hydrant(s) to facilitate operations such that fire-fighters are able to utilise the fire hydrants located beneath the covered awnings (refer to Figure 13.1 for further details). The external 'fall back' fire hydrants are to be located within 60m if the fire hydrants located beneath the covered awnings, be located as close as possible to the perimeter vehicular access location and furthermore are to be design and installed to achieve attack fire hydrant performance; and
- Permit fire hydrants coverage to be calculated based on Clause 3.5.3.3(b) of AS2419.1:2017, where the building parts receiving coverage are within 70m of the external fire hydrants.

Furthermore, the FRNSW has provided in-principal support of the above design issues as Appendix J.

13.7.2 Sprinkler Effectiveness in Storage Facilities

The subject building is installed with an automatic fire sprinkler system in accordance with AS2118.1:2017 unless otherwise addressed herein. More specifically, the Class 7b warehouse portions of the subject building (including dangerous goods enclosures) is to be sprinkler protected with the installation of a Storage Sprinkler system.

With the presence of the sprinkler systems throughout the building, the potential risk associated with the development and spread of fire, generation of smoke, distress to building elements, occupant and fire-fighter exposure to tenable conditions is significantly minimised. Experimental evidence and numerical studies (Beever and Britton, 1998, Cooper, 1995a, Chow, 1991) have demonstrated that sprinklers are very effective in controlling and suppressing fires. When a sprinkler system is activated in a room fire, not only the heat release rate of the burning fuel is reduced or controlled to a relatively small level, but also the gas temperature inside the room of fire origin can be reduced or maintained due to the cooling effect of water spray. Damage to the lightweight construction and the plasterboard barrier is likely to be minimal and the risk to life safety is extremely low (Marryatt, 1988).

Furthermore, automatic sprinklers have an inherently high reliability. The extensive study by Marryatt (1988) covering the past century of sprinkler protected buildings indicated that sprinklers systems which are soundly managed may have reliability as high as 99.5%. Research findings by Nash and Young (1991) and Bukowski et al. (1999) also confirmed the high reliability of sprinkler systems. Appendix E provides statistics and referenced literature of sprinkler reliability.

As stated in the aforementioned section, sprinkler systems are almost certain to activate upon detection of a potential fire due to a high reliability factor. With sprinkler activation, it is evident that the effect of sprinklers on a fire is to wet down potential fuel sources, control or suppress the burning process and to cool the resultant smoke layer. It has been cited that the resultant smoke temperatures in a sprinkler-controlled fire are of the order of 100°C -120°C (CIBSE 1997; Sekizawa, 1996).

Therefore, it is considered that the sprinkler system will reduce the temperatures of smoke to the degree necessary that the elements of the building will not fail as temperatures do not exceed the temperature limits of the structural elements. Furthermore, the efficacy of the sprinkler system and based on the expected low temperatures, occupant and fire-fighter life safety is unlikely to be compromised.

13.7.3 Fire Hydrant Booster Assembly

The proposed design with respect to the fire hydrant booster assembly location will allow the attending fire fighters to undertake an attack on a potential fire to the degree necessary and will not impede their ability to undertake standard operation procedure.

The following mitigating effects are noted:

- The building is provided with an automatic sprinkler system throughout, including under the awnings.
- The sprinkler system shall be designed and installed in accordance with Clause E1.5 from Volume One of the NCC and AS2118.1:2017. In the event of a fire initiating within the building it is almost certain that the sprinkler system will activate to either control or extinguish a fire. Sprinkler systems are both very reliable and very effective, so it is likely that fire brigade personnel will not encounter a larger fire due to this noncompliance, as the fire would have been controlled or extinguished by the sprinkler system.

It is therefore considered that the design issues identified with respect to the fire hydrant system does not represent an additional risk to life safety or fire brigade intervention.

Johnston Crescent shall form part of the principle entrance for vehicles to the site. As detailed above, the fire hydrant booster assembly faces the emergency vehicular access road in lieu of the main entry to the site. Therefore, there is the potential for Fire Brigade personnel to be delayed/hindered whilst undertaking intervention based on Standard Operational Guideline's (SOG's).

Upon notification of a fire within the subject building, the attending fire crews shall likely approach the site from Huntingwood Fire Station and Bonnyrigg Heights Fire Station via Johnston Crescent. As fire crews approach the site it is expected that they would be simultaneously evaluating the scene, identifying the location of the fire and the building entrances. In this regard, the location of the fire hydrant booster assembly shall be visible to approach crews whilst travelling along perimeter vehicular access road.

To assist with the attending fire fighters, site wide block plans shall be provided which can be readily seen by FRNSW upon arrival to the site from Johnston Crescent. The block plans shall be weatherproof engraved A1 size illustrating all buildings onsite as well as key fire services (incl. fire hydrant booster location, fixed onsite fire pump sets, sprinkler booster assembly, main FIP location, static fire water tanks, vehicular access road etc.).

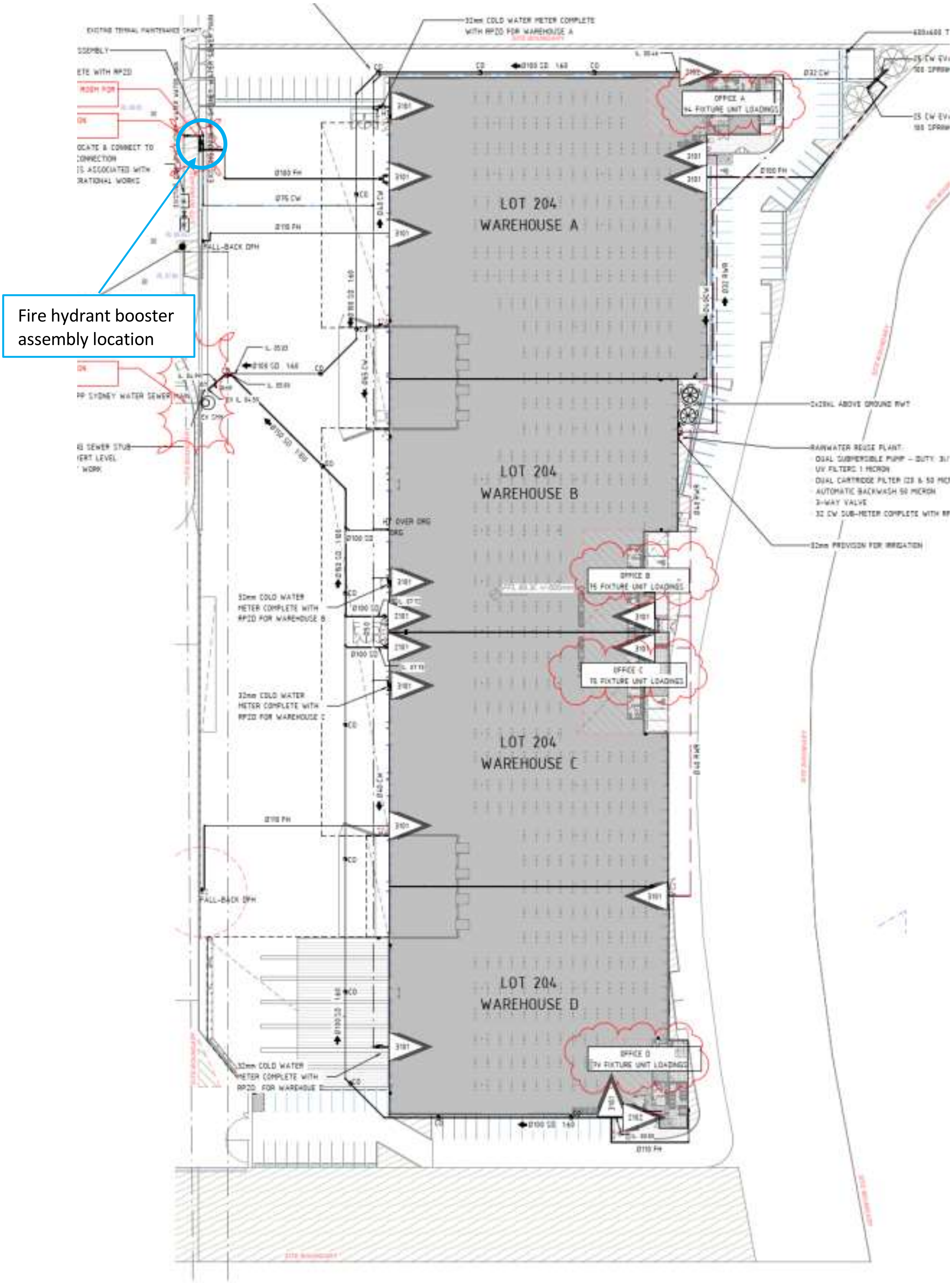


Figure 13.2: Fire hydrant booster location

The Fire Brigade require an understanding of the location of fire-fighting equipment (e.g. hydrants, water tanks & sprinkler booster assembly) prior to undertaking intervention activities. In order to inform attending fire crews of the fire-fighting equipment contained onsite, block plans incorporating floor plans/mud maps shall be located at the booster assembly and main Fire Department Control and Indicating Equipment (FDCIE) location. In this regard, attending fire crews shall be provided with the necessary information upon arriving at any of the aforementioned locations. It is also important to note that block plans shall be documented in accordance with Section 7.11 of AS2419.1-2005.

13.7.4 Omission of Fire Rated Shield Panels to Fire Hydrants

As part of the Performance Solution, it is proposed to permit fire hydrants without the requirement for fire rated shield panels throughout the entire site.

AS2419.1:2017 was published on 06-11-2017 by Standards Australia which proposed amendments to be adopted for fire hydrant installations.

In reference to the above standard AS2419.1:2017 – Section 3.5.5 – Protection of fire hydrants (refer to Appendix K), a concession is provided for sprinkler protected buildings whereby the protective requirements (i.e. radiant heat shield achieving FRL of 90/90/90 extending 2m either side and 3m above the upper hose connections) need not be applied. As per Clause 3.5.5.2 of the standard AS2419.1:2017, the following is noted:

"Where a sprinkler system is installed throughout a building in accordance with AS 2118.1, AS2118.4 or AS 2118.6, the external fire hydrant(s) located within 10m of the building need not be protected in accordance with the requirements of Clause 3.5.5.1".

Based on the above concession, it is considered that a fully compliant and properly installed sprinkler system within the subject building shall be capable of providing a suitable level of protection to the attending Fire Brigade personnel. The sprinkler system will limit fire spread and radiant heat exposure imposed upon fire-fighter personnel undertaking their operations.

13.7.5 Fire Hydrants Located Beneath Awning Structures

As described above, the following qualitative evaluation is provided in order to demonstrate that the Fire Brigade intervention activities are facilitated with consideration of the hydrant being located beneath the covered awnings. To this affect the following qualitative arguments are presented:

- Full coverage of the warehouse is afforded if the identified fire hydrants are located under the awnings and are considered to be external whereby the warehouse is considered to comply with Volume One of the NCC to achieve full coverage.
- Additional fall-back hydrants are provided as a redundancy to assist the attending fire-fighters in fire control and suppression activities where an external fire hydrant under the awning may be rendered unusable and difficult to access during fire-fighting operations.
- The purpose of the awning is to cover the loading area which is not intended for storing goods as it is used as transit parking bays for the delivery trucks during loading and unloading process. Therefore, it is unlikely that the hydrants would be blocked by an obstruction.
- The external awnings are located at a height of approximately 6.0m clear above the finished floor level (i.e. hard stand level) and are fully open on three (3) sides which will allow for significant venting of any potential hot smoke that may impact on the fire-fighters adopting the hydrants. The natural venting capacity is illustrated in Figure 13.3.
- External hydrants are provided around the building to facilitate the attending fire-fighters to adopt the most appropriate fire hydrant location. It is considered unlikely for attending fire-fighters to adopt the external hydrant that is located within closer proximity to a potential fire. Therefore, should the external fire hydrants located beneath the external awning be inaccessible, additional fall-back hydrants (i.e. achieving attach hydrant performance) are provided to facilitate Fire Brigade intervention activities. The fall-back hydrants are to be located no greater than 60m from the fire hydrants located beneath the covered awning.

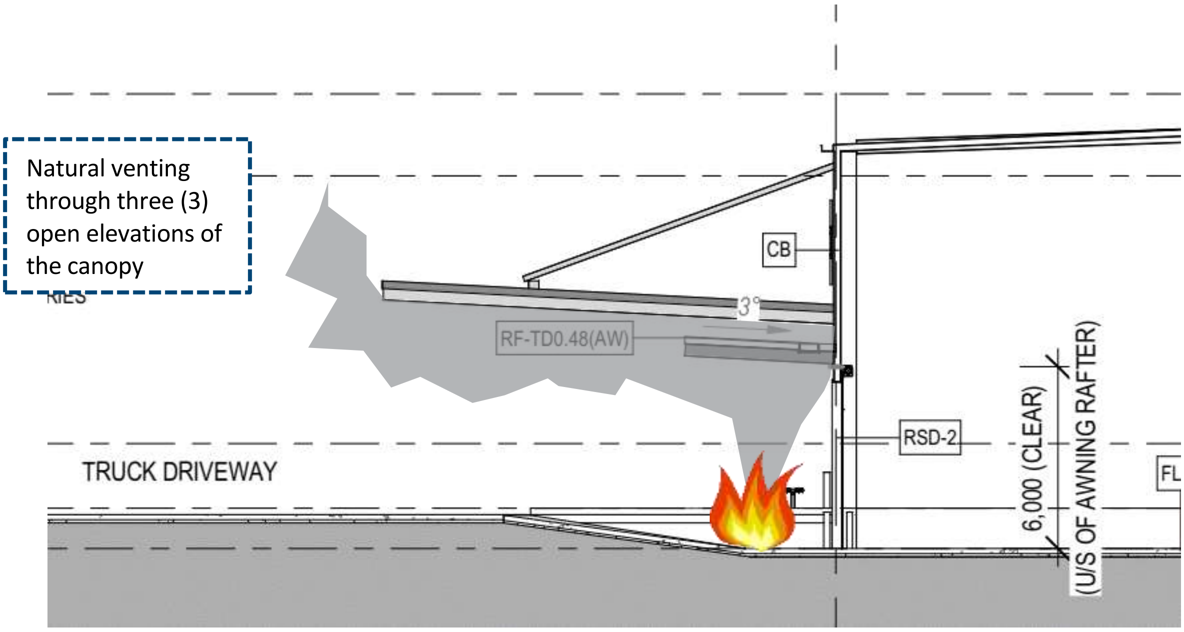


Figure 13.3: Natural venting through external awning (indicative representation)

- The entire building shall be provided with automatic fire sprinkler protection in accordance with AS 2118.1:2017. The sprinkler system shall be as follows:
  - The Class 5 office portion of the subject building is to be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 appropriate to 'Light Hazard' classification; and
  - The Class 7b warehouse portion of the subject building is to be sprinkler protected with the installation of K22 Storage Sprinkler or equivalent incorporating 'fast response' type heads. The activation temperature of Storage sprinkler heads shall be no more than 100°C; and
  - Covered awnings forming part of the Class 7b portion of the subject building shall be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 to 'Ordinary Hazard 3' classification unless otherwise Storage Sprinklers are proposed.
- Where required, the Storage Sprinkler system shall comply with the Factory Mutual (FM Global) Property Loss Prevention Data Sheet 2-0, "Installation Guidelines for Automatic Sprinklers" and Property Loss Prevention Data Sheet 8-9, "Storage of Class 1, 2, 3, 4 and Plastic Commodities." The design and installation of the Storage Sprinkler system shall be in strict accordance with the building geometry/height, achieve required minimum clearance, commodity/storage layout/height & hydraulic pressure/flow requirements.

13.7.6 Measurement of Hydrant Hose Coverage

The measurement of fire hydrant hose coverage to the entirety of the building shall be in line with AS2419.1:2017 in lieu of AS2419.1:2005. In this regard, all parts of the building shall be within 70m (i.e. 2 x 30m standard hose length + 10m spray) of the fire appliance when utilised as a feed from an external hydrant location. The general measurement of hydrant hose coverage is noted to be no different to the AS2419.1:2005 Australian Standard with the exception that the requirement for a minimum 1m length of hose to extend into any room served will not be provided (i.e. Part (ii) of Clause 3.2.2.2(b) of AS2419.1:2005). Table 13.2 provides a comparison of the relevant Australian Standard provisions.

Table 13.2: Comparison of Australian Standard provisions

AS2419.1:2017 Provisions	AS2419.1:2005 Provisions
Clause 3.5.2(a) (a) The street hydrant(s) shall be shown to be in accordance with the requirements for external feed hydrants with regard to flow, pressure and location. The street hydrant(s) shall – (i) Be capable of providing not less than the minimum flow and pressure for external feed fire hydrants; and **(ii)** Be located in accordance with the requirements of Clause 3.5.3.1 and 3.5.3.3. **Clause 3.5.3.3(b)** (b) All portions of a building or open yard that are protected by an external attack fire hydrant, located no more than 50m from a hardstand areas shall be within 70m of the external attack fire hydrant.	**Clause 3.2.2.1** Street fire hydrants may be considered as external fire hydrants provided they comply with the requirements of this Standard for flow, pressure and location, with either a single or double outlet fire hydrant being acceptable in this case. Street fire hydrants may be used to provide total or partial coverage provided a fire brigade booster assembly is not incorporated in the system. **Clause 3.2.2.2(b)** (b) When installed as a feed fire hydrant [See Figure 3.2.2.2(a), (b), (d) and (e)], within 20m of a hardstand such that when a fire brigade pumping appliance is connected to it – (i) all portions of the building shall be within reach of a 10m hose stream, issuing from a nozzle at the end of a 60 m length of hose laid on the ground; and (ii) a minimum of 1m of hose shall extend into any room served.

With reference to Table 13.2, the 2017 Australian Standard omits the requirement for 1m hydrant hose length of hose to extend into any room served. The intent behind this is to provide a greater level of flexibility with respect hydrant hose coverage from an external location. More specifically, the 2017 Australian Standard recognises that attending fire crews may not necessarily enter a room of fire origin to conduct water application activities as it may present additional risks. In this regard, it may be safer for fire crews to apply fire water from an adjacent area in lieu of entering a fire affected room, predicated on full coverage being achieved.

With consideration to the open nature of the facility and the layout of the racking, the attending fire fighters are able to run the hose reel out in relatively straight lines to provide full coverage without the need to enter a room to conduct water application activities. The fire services engineer has provided coverage drawings which demonstrate full coverage is achieved (refer to Figure 13.1).

13.8 Discussion of Assessment Outcomes

The assessment has demonstrated that a fire scenario within the subject building will not have a detrimental impact on Fire Brigade intervention activities has been facilitated. The acceptance criterion based on a comparative basis has therefore been satisfied.

The qualitative and quantitative evaluation has demonstrated that the fire hydrant system provisions serving the subject site do not present an adverse impact for attending Fire Brigade personnel in the event of an emergency fire situation. Fire crews are provided with appropriate hydrant shielding, hydrant coverage and fall-back hydrants for use in the unlikely case where an external hydrant is threatened by a fire.

The acceptance criterion has been based on the ability for attending fire crews to deploy Standard Operational Guideline's (SOG's) and has been satisfied. Therefore, it is deemed to satisfy the Performance Requirement of EP1.3 from Volume One of the BCA.

14. Sprinkler Booster Assembly and Pump Room

14.1 Background to the Issue

It is proposed to permit the sprinkler booster assembly and pump room are not located adjacent to the principal vehicular entry, at the site boundary and not within direct line of sight of the main entry to the building.

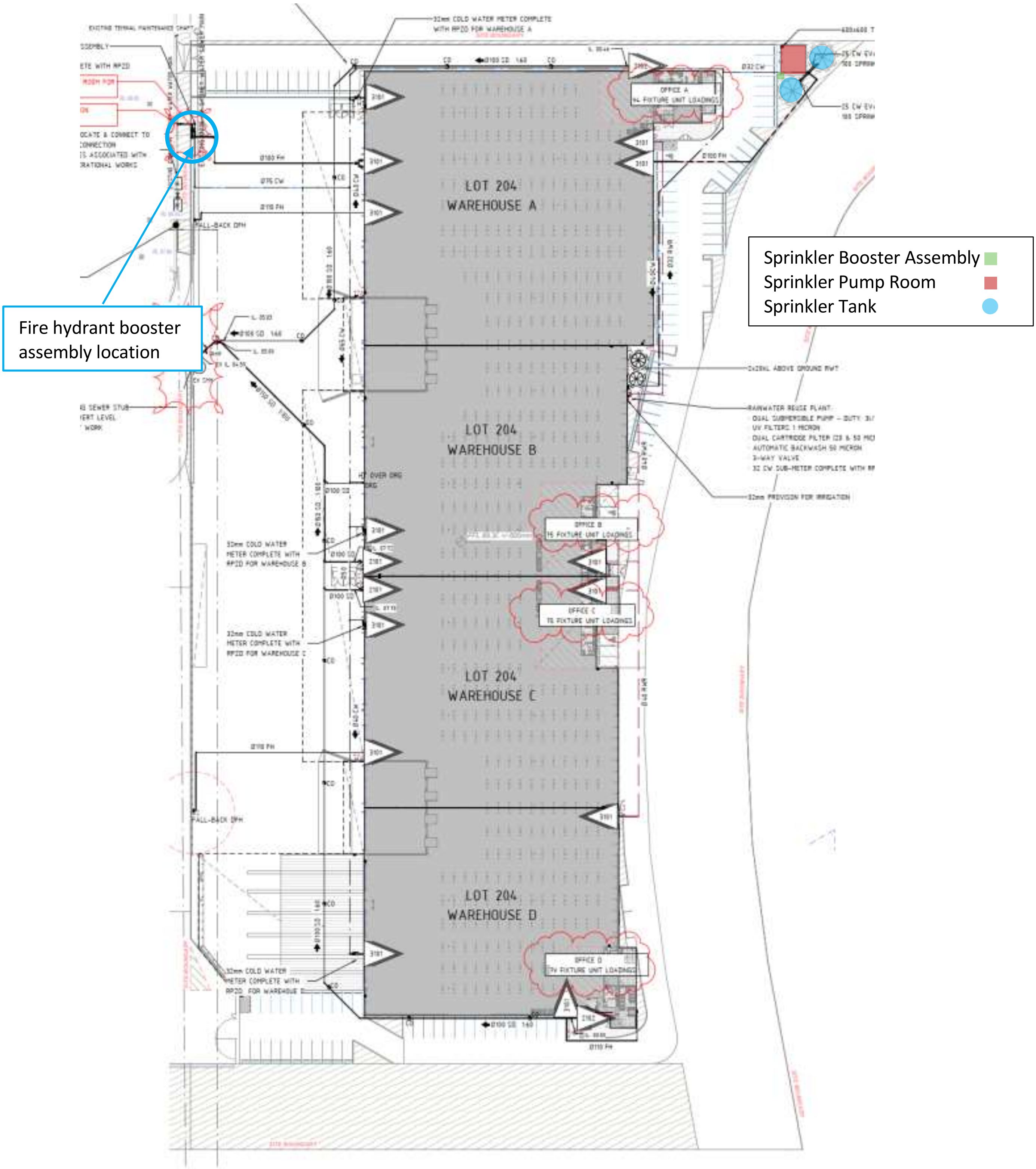


Figure 14.1: Location of sprinkler booster assembly with respect to FRNSW access to site

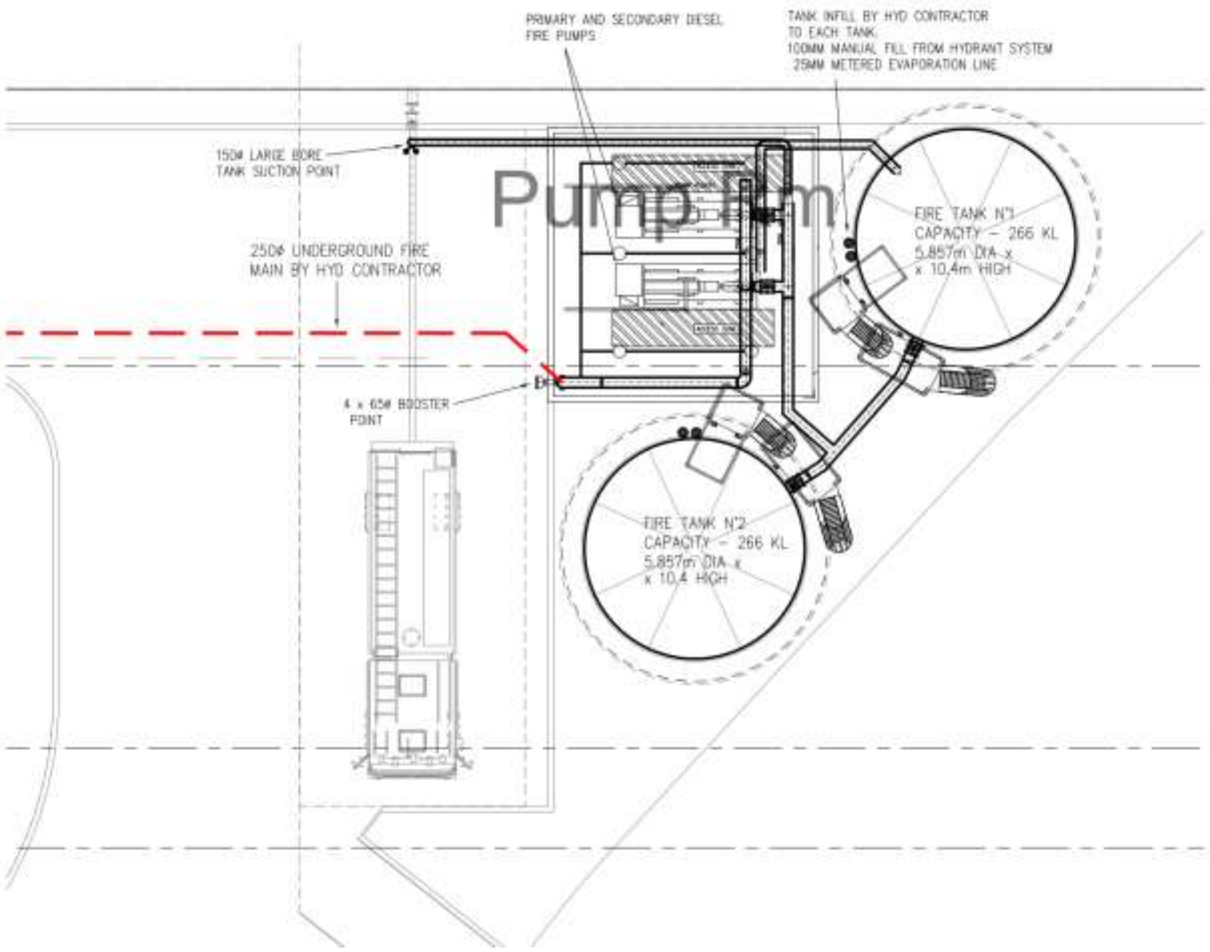


Figure 14.2: Sprinkler booster assembly and Pump room details

14.2 Assessment Methodology

In accordance with the NCC Clause A2.2 *Assessment Methods* the following assessment method has been adopted to determine that the *Performance Solution* has met the relevant *Performance Requirements* EP1.4*.*

Table 14.1: Method of Analysis

Identified Design Issue	BCA Assessment Method	IFEG Method of Analysis
It is proposed to permit the sprinkler booster assembly and pump room are not be located adjacent to the principal vehicular entry, at the site boundary and not within direct line of sight of the main entry to the building.	A2.2(2)(b)(ii) Other Verification Method as the appropriate authority accepts for determining compliance with the Performance Requirements.	A qualitative approach has been assessed the acceptability of the sprinkler assembly location which has been assessed with direct consultation and input from the FRNSW.

14.3 Hazard Specific to Sprinklers Booster Assembly and Pump Room

The Guide to the NCC (ABCB, 2019) clarifies that automatic fire suppression systems are intended to contain and extinguish fire, controlling or limiting fire development, and often extinguishing fires before they endanger occupants, or else allowing additional time for occupants to evacuate. It is therefore considered that the main hazard associated with the identified design issue relates to:

- Potential for fire brigade to encounter a larger fire due to delayed notification.

14.4 Hazard Mitigation

In light of the above hazards, the following is noted:

- Provide site wide block plans which can be readily seen by FRNSW upon arrival to the site from Johnston Crescent. The block plans shall be weatherproof engraved A1 size illustrating all buildings onsite as well as key fire services (incl.

fire hydrant booster location, fixed onsite fire pump sets, sprinkler booster assembly, main FIP location, static fire water tanks, vehicular access road etc.); and

- The building is provided with an automatic sprinkler system throughout, including under the awnings.
- The sprinkler booster assembly, sprinkler tank and pump house to be positioned at the north-east of the site in lieu of at the main entry of the site; and
- Building elements throughout shall be constructed in accordance with the minimum Fire Resistance Levels (FRL) commensurate with Type C fire resisting construction.

14.5 Methodology

The evaluation of the performance design solution has been based on a qualitative risk-based assessment. A qualitative assessment is considered appropriate (as the appropriate authority accepts for determining compliance with the relevant Performance Requirement) which aims to provide compliance with the relevant Performance Requirements of the NCC by providing fire safety protective and mitigation measures for the performance solution. The design issue pertaining to the variation to the sprinkler system has been assessed with respect to the hazards and the potential impact imposed towards the attending fire brigade personnel.

14.6 Acceptance Criteria

The basic objective and intent of this analysis pertains to the life safety of the attending fire brigade personnel. The assessment methodology has considered the Standard Operational Procedures (SOP's) following direct consultation with the FRNSW. The acceptance criterion has been met having demonstrated that the proposal to permit the location of the sprinkler booster assembly and pump room is satisfactory to the FRNSW such that the proposed design and layout maintains the efficacy of fire-fighting operations and the deployment of safe Standard Operational Procedures (SOP's). The acceptability of the proposed sprinkler system has also considered the 'in-principle' agreement from FRNSW.

14.7 Evaluation of Sprinkler Booster Assembly and Pump Room Location

The proposed design with respect to the sprinkler booster assembly and pump room location will allow the attending fire fighters to undertake an attack on a potential fire to the degree necessary and will not impede their ability to undertake standard operation procedure.

The following mitigating effects are noted:

- The building is provided with an automatic sprinkler system throughout, including under the awnings.
- The sprinkler system shall be designed and installed in accordance with Clause E1.5 from Volume One of the NCC and AS2118.1:2017. In the event of a fire initiating within the building it is almost certain that the sprinkler system will activate to either control or extinguish a fire. Sprinkler systems are both very reliable and very effective, so it is likely that fire brigade personnel will not encounter a larger fire due to this noncompliance, as the fire would have been controlled or extinguished by the sprinkler system.

It is therefore considered that the design issues identified with respect to the sprinkler system does not represent an additional risk to life safety or fire brigade intervention.

Johnston Crescent shall form part of the principal entrance for vehicles to the site. As detailed above, the sprinkler booster assembly faces the emergency vehicular access road in lieu of the main entry to the site. Therefore, there is the potential for Fire Brigade personnel to be delayed/hindered whilst undertaking intervention based on Standard Operational Guideline's (SOG's).

Upon notification of a fire within the subject building, the attending fire crews shall likely approach the site from Huntingwood Fire Station and Bonnyrigg Heights Fire Station via Johnston Crescent. As fire crews approach the site it is expected that they would be simultaneously evaluating the scene, identifying the location of the fire and the building entrances. In this regard, the location of the sprinkler booster assembly shall be visible to approach crews whilst travelling along perimeter vehicular access road. To assist with the attending fire fighters, site wide block plans shall be provided which can be readily seen by FRNSW upon arrival to the site from Johnston Crescent. The block plans shall be weatherproof engraved A1 size illustrating all buildings onsite as well as key fire services (incl. fire hydrant booster location, fixed onsite fire pump sets, sprinkler booster assembly, main FIP location, static fire water tanks, vehicular access road etc.)

The Fire Brigade require an understanding of the location of fire-fighting equipment (e.g. hydrants, water tanks & sprinkler booster assembly) prior to undertaking intervention activities. In order to inform attending fire crews of the fire-fighting equipment contained onsite, block plans incorporating floor plans/mud maps shall be located at the booster assembly and main Fire Department Control and Indicating Equipment (FDCIE) location. In this regard, attending fire crews shall be provided with the necessary information upon arriving at any of the aforementioned locations. It is also important to note that block plans shall be documented in accordance with Section 7.11 of AS2419.1-2005.

14.8 Assessment Outcomes

Based on the assessment presented above, it is considered that fire brigade intervention will not be affected by the identified design issues relating to the automatic sprinkler system. It is therefore considered that the Performance Requirement of EP1.3 from Volume One of the NCC is satisfied. This conclusion is contingent on the requirements as detailed in Section 16 being implemented into the design.

15. Exit Signs

15.1 Background to the Issue

Exit signs and directional exit signs are to be installed throughout the building in accordance with clauses E4.5, E4.6 and E4.8 of the BCA and AS2293.1:2018 with the exception that the mounting heights of exit signage within the warehouse portion of the building. In this instance, it is proposed to permit the top of the exit signs to be mounted 5.5m above the finished floor level within the warehouse areas only in lieu of 2.7m as otherwise required by the prescriptive provisions from Volume One of the BCA.

15.2 Assessment Methodology

In accordance with the BCA Clause A2.2 *Assessment Methods* the following assessment method has been adopted to determine that the *Building Solution* has met the relevant *Performance Requirement EP4.2*.

Table 15.1: Methods of Analysis

Identified Design Issue	BCA Assessment Method	IFEG Method of Analysis
Directional and non-directional exit signs are to be installed throughout the building in accordance with Part E4 from Volume One of the BCA and AS2293.1:2018 with the exception that the mounting heights of exit signage within the warehouse portions of the building. In this instance, it is proposed to permit the top of the exit signs to be mounted 5.5m above the finished floor level within the warehouse portion only in lieu of 2.7m as required by the prescriptive provisions from Volume One of the BCA.	A2.2(2)(b)(ii) Verification method as the relevant authority accepts for determining compliance with the performance requirements. The associated Performance Requirements to be met is EP4.2	A 'deterministic absolute' approach whereby an occupant and fire-fighter life safety assessment has been developed in the form of an ASET/RSET timeline analysis.

Fire and smoke modelling has been conducted to determine whether or not the smoke layer will impact the abilities for occupants to visualise the exit signs.

15.3 Hazard Specific to Exit Signs

The 'Guide to the BCA' (ABCB, 2019) states that the intent associated with mounting exit signage at the prescribed height is "t*o ensure exit signs are clearly visible at all times when the building is occupied."* It is therefore, considered that the main hazards specific to the issue to be considered in the assessment are:

- The potential for fire by-products (smoke and toxic gasses) to restrict the path of occupant travel (i.e. potential for tenability limits to be exceeded within the path of travel); and
- The potential for smoke to obscure the view of exit signs during a potential fire situation.

15.4 Hazard Mitigation to Exit Signs

The Guide to BCA (ABCB 2019) identifies the hazards as being directly related to the facilitation of occupant evacuation in the event of an emergency fire situation. In this regard, the following is noted:

- The distribution centre is provided with an automatic sprinkler system that is designed to suppress a fire. The outcome of effective fire sprinkler suppression system operation is to mitigate smoke production through suppression. The propagation of smoke is significantly reduced after sprinkler head activation; and
- Exit Signage located and installed in accordance with Clauses E4.5 & E4.6 from Volume One of the BCA and AS/NZS 2293.1 with the exception of increased mounting heights of "directional exit' signs within the path of travel to an emergency exit. The directional exits signs are to be "JUMBO" exit signs such that occupants can visualise the exit signs from a greater distance and as a result enhance the overall way finding performance; and
- The occupants within the building will be familiar with their surroundings and will be familiar with the basic internal racking layout (way finding) design of the distribution centre; and
- Rationalised smoke hazard management which shall be designed and installed based on the building geometry, potential fire hazard and occupant numbers/characteristics and occupant/fire-fighter tenability limits.
- The large internal volume space provides a natural smoke reservoir for the hot smoke and gases to accumulate allowing additional time for safe occupant evacuation.

15.5 Methodology

The methodology adopted to address the exit sign provisions has been quantitatively assessed analysing the fire and evacuation modelling outcomes. In this instance, an ASET/RSET assessment has been undertaken demonstrating that the smoke layer height is maintained above the top of the exit sign (mounted 5.5m above the finished floor level) for at least the time taken for occupants to evacuate the storage portion of the building.

Furthermore, the proposed mounting height of the exit signs has been deemed acceptable with respect to occupant visibility and the viewing angle of the exit signage.

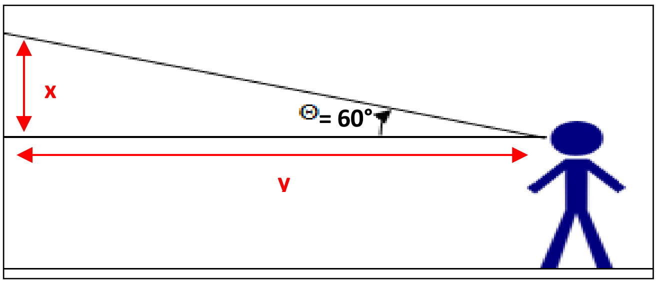


Figure 15.1: Illustration denoting the viewing angle and field of vision

- **Signage Size**
  - The signage height between the proposed and DtS design shall be designed in accordance with BCA Clause E4.5 & E4.6 and AS/NZS 2293.1-2005; and
- **Field of Vision (x)**
  - DtS design: exit signs are required to be mounted no greater than 2.7m above the finished floor level; and
  - Proposed design: to permit the top of the exit signs to be mounted 5.5m above the finished floor level within the warehouse portion.
- **Viewing Angle (ϴ)**
  - It is noted that the normal field of vision by occupants is approximately 60° (BS 5499-10, 2006) above the horizontal eye line of sight.
- **Viewing Distance (y)**
  - The analysis shall evaluate multiple viewing distances (i.e. 5m, 10m, 15 & 20m) with results demonstrating that the proposed mounting exit sign height is within the same field of vision when compared to a DtS design (i.e. 2.7m).

15.6 Acceptance Criteria

The acceptance criteria has been met by demonstrating that the smoke layer height can be maintained above the top of the exit sign (ASET) which is mounted 5.5m above the finished floor level for a period of time no less than the time taken for occupants to evacuate the storage portion of the building (RSET). Therefore, the following acceptance criteria has been met:

$$\textbf{ASET}_{\text{smoke layer 5.5m above the FFL}} > \textbf{1.0 x RSET}$$

Furthermore, the proposed mounting height of the exit signs has been deemed acceptable with respect to occupant visibility and the viewing angle of the exit signage. The proposed mounting exit sign height has been deemed acceptable if within the same field of vision to a DtS compliant design (i.e. 2.7). It has been demonstrated that the proposed exit sign mounting height will not impact the building occupant's ability to visualise the exit signs.

15.7 Evaluations of Exit Signage Height

As identified above, it is proposed to increase the mounting heights of exit signage within the ground floor level of the warehouse portions of the building to exceed the maximum levels as nominated by AS2293.1:2018 and Clause E4.5, E4.6 & E4.8 from Volume One of the NCC. The purpose of increasing the exit sign mounting heights is to allow for pallet lifts to freely move through racking passageways and high storage configurations.

Fire and smoke modelling has been undertaken to assess visibility conditions within the ground floor level within each warehouse throughout the evacuation process. The fire modelling conducted for the subject building has demonstrated that the hot smoke layer would remain above a height of the following whereby the directional exit signage is not expected to become obscured for a period such that sprinkler activation and pre-movement times are accounted for.

According to the fire and smoke modelling results illustrated in Figure 15.2, with reference to the core fire scenarios, it has been demonstrated that the smoke layer maintained above 5.5m above the finished floor level at approximately 380 seconds (fire scenario HP01C_10.4W1) and 290 seconds (fire scenario HP03C_10.4W3). The modelling outcomes have demonstrated that occupants are afforded with sufficient time to view the exit signage whilst they evacuate the ground floor level warehouse portions. Therefore, it is considered that 1.0 x RSET has been achieved.

Based on the occupant evacuation analysis, it is considered that occupants are provided with adequate time to evacuate the building prior to the smoke layer descending the prescribed exit signage height within each warehouse (i.e. obscuration of the exit signage). Therefore, the ability for occupants to view the exit signs exceeds the duration for occupants to evacuate the ground floor level warehouse portions of the subject building.

Largest Warehouse Enclosure (Warehouse A)

- ASET smoke layer 5.5m above the FFL > 1.0 x RSET
- 380 seconds > 220 seconds

Smallest Warehouse Enclosure (Warehouse D)

- ASET smoke layer 5.5m above the FFL > 1.0 x RSET
- 290 seconds > 205 seconds

It should be noted that this method of analysis is consistent with regard to occupant life safety and the exit signs being mounted no more than the prescribed distances within each warehouse above the finished ground floor level will not be obscured for occupant evacuation. In this instance, the occupants located in the area of fire origin may act far earlier to commence evacuation than what is considered conservative when addressing the pre-movement phase associated with the aforementioned evacuation assessment.

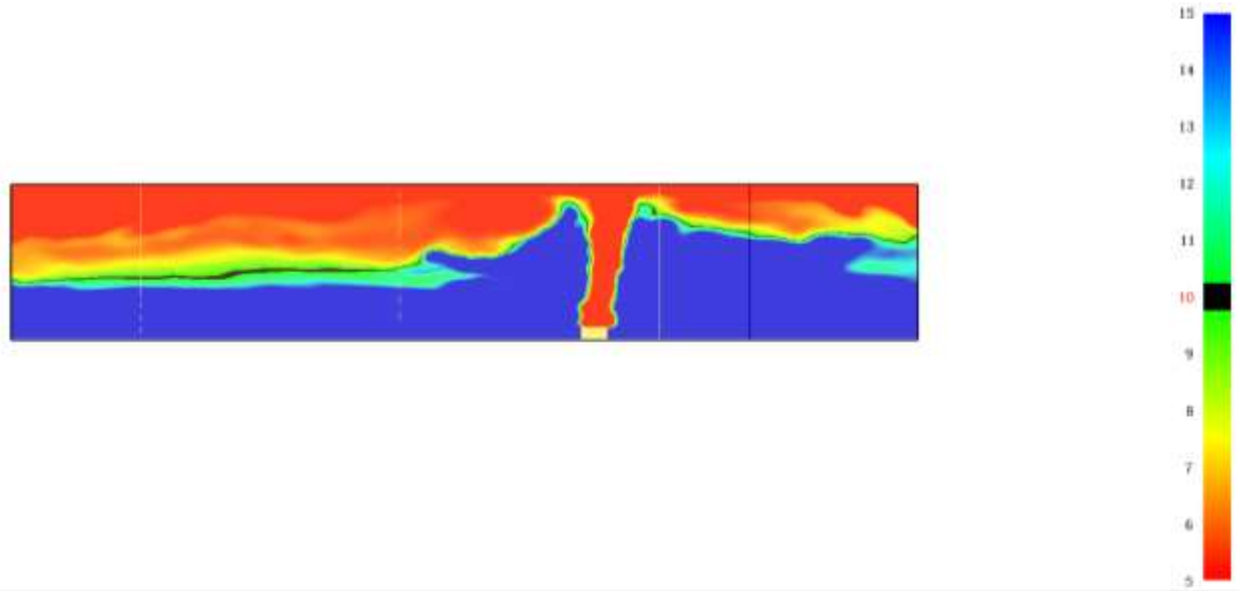


Figure 15.2: Visibility slice at 380 seconds (HP01C_10.4W1) (Smoke layer maintained above 5.5m above FFL)

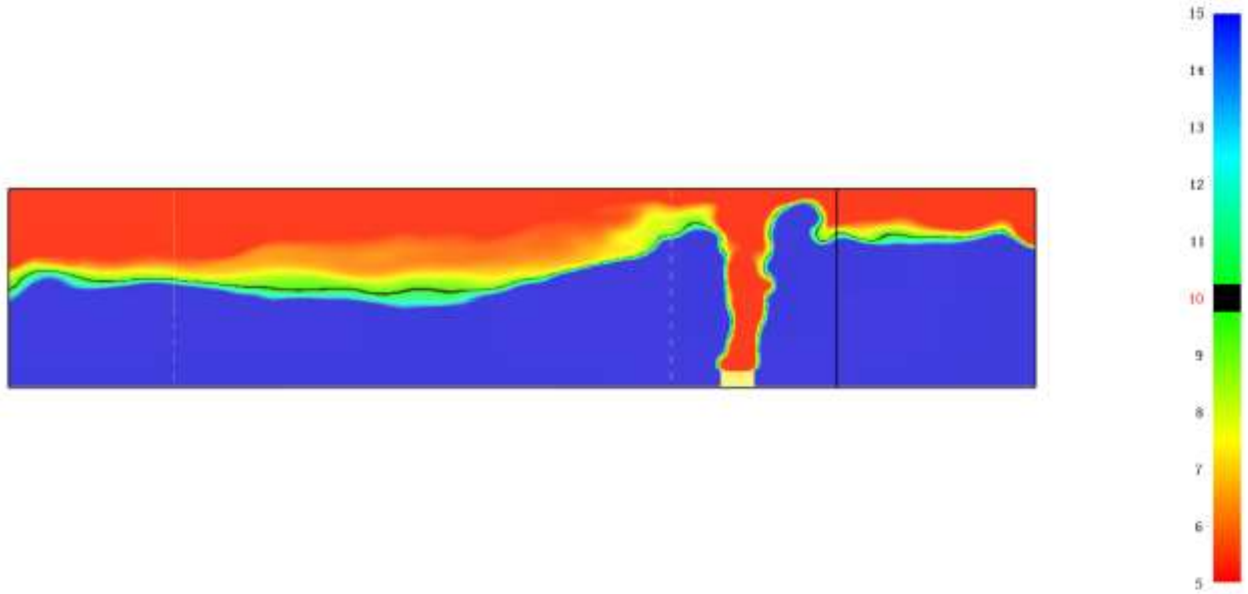


Figure 15.3: Visibility slice at 290 seconds (HP03C_10.4W3) (Smoke layer maintained above 5.5m above FFL)

According to literature (i.e. SFPE, 2003), visibility requirements for escape depend to a large extent on the size of an enclosure and occupants' familiarity with escape routes. Peoples' response to obscuration of vision and its detrimental effects on movement speed and wayfinding efficiency is highly variable as familiarity and fire cues all become part of the evacuation process.

Humans have a horizontal field of view of more than 200° with the central 60° zone being identified as the binocular field. The vertical field of view ranges from 70° below horizontal to 60° above horizontal. Visual presence of a sign within a field of view is highly likely to result in recognition and consequently wayfinding. As shown in Figure 15.4 and Table 15.2 the exit signs located at 2.7m and 5.5m above the floor level are very much within the field of view of a person with average height at distances varying from 10m to 50m.

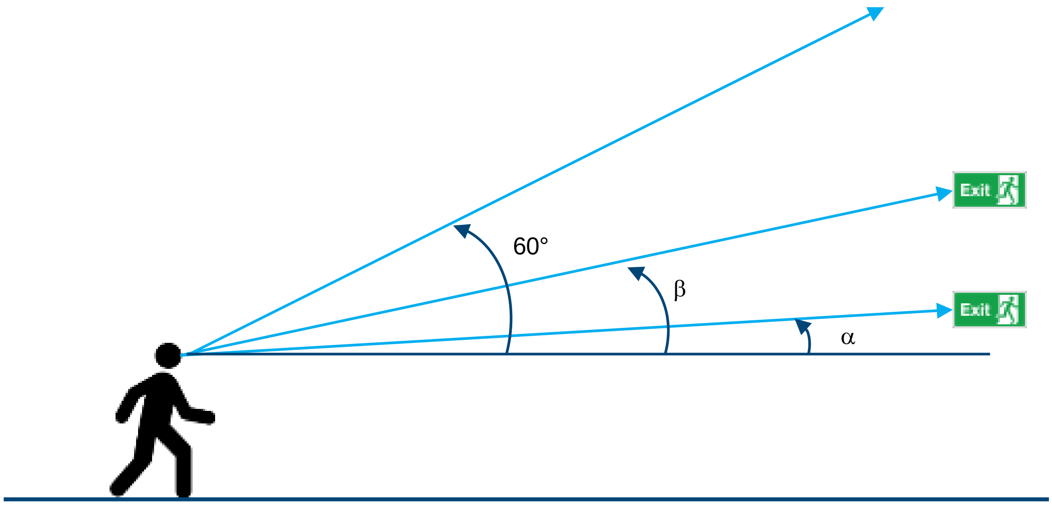


Figure 15.4: Field of view for exit signs at different heights

Table 15.2: Field of view for exit signs at different heights

Distance between occupant and the sign location (m)	Exit sign at 2.7 m (α = angle degrees above horizontal)	Exit Sign at 5.5m (β= angle degrees above horizontal)
10	5.1	20.3
20	2.6	10.5
30	1.7	7.0
40	1.3	5.3
50	1.0	4.2

Note: The above calculation is based on an average person height of 1.8m.

While the "visibility" of the sign is the key factor here, since it also implies perception, the term "visuality" is deemed more appropriate than "visibility" in this context. In a fire safety engineering framework the smoke layer development needs to be quantified with respect to time and density. The visibility of the sign will depend on multiple parameters including smoke layer height, lines of sight within an enclosure with obstacles (i.e. racks) and in some instances visual access to the sign itself. The subject warehouse portions, as previously stated, shall have racking throughout their main distribution floors within straight lines of travel along each aisle. There shall be no dead end corridors in either the warehouses and furthermore, at the end of each racking aisles the occupants are expected to have the ability to see the exit locations.

The building occupants are expected to be awake, alert and predominantly able bodies and familiar with the building layout or emergency procedures. As a result of the relatively small geometries, exit signage and multiple exit locations, wayfinding and familiarisation within the warehouses contained within the subject building is not expected to pose any significant life safety concerns for the building occupants.

As discussed in Section 11, the exit travel distances are not expected to increase the risk of occupant exposure to untenable conditions. Based on the fire and smoke modelling outcomes, the increased exit sign height is not expected to inhibit occupants from seeing and assessing the provided exits. As such the occupants are expected to be able to visualise the exit signs well before conditions reduced to a level which increases the risk of occupant exposure to untenable conditions. It is noted that the fire and smoke modelling conducted for the main warehouse portions contained within the subject building has demonstrated that the hot smoke layer does not obscure occupant visibility.

The modelling has demonstrated that any signage mounted at the prescribed distances above the finished ground floor level would also remain visible for the duration of evacuation and as such the acceptance criterion has been satisfied.

15.8 Assessment Outcomes

The quantitative evaluation undertaken above has demonstrated that the mounting height of the exit signage above the prescriptive requirement of 2.7m does not present a negative impact on the wayfinding performance of occupants in the event of an emergency fire situation. The assessment has demonstrated that an expected fire scenario within the warehouse portions of the building is not likely to obstruct the respective exit signage for a duration required for effective occupant egress performance.

Based on the rationale presented it is therefore considered that the proposed design with the proposed mounting height of the exit signs is considered to satisfy the Performance Requirement of EP4.2 from Volume One of the NCC. This conclusion is contingent on the recommendations in Section 16 being implemented into the design.

16. Conclusion

16.1 General

The Fire Safety Engineering assessment detailed in this report demonstrates that the proposed Performance Solution aspects of the building solution have been shown to meet the corresponding identified Performance Requirements of the BCA as listed in Table 3.1.

The assessment and verification methodologies employed have been in accordance with the requirements of the BCA and conform to the principles of IFEG.

The building incorporates a range of fire safety measures in accordance with the relevant Australian Standards. In summary, the BCA defines the fire safety measures and their applicable standards required to be installed within buildings. Unless otherwise stated, the applicable standard of fire safety system installation (active and passive) must be compliant with the BCA and the relevant Australian Standards.

The Client is to ensure that the relevant stakeholders and services consultants that have been involved in the project are in agreement with the proposals made in this document. Furthermore it is the responsibility of the other designers and consultants (not SFS) to complete the detailed design of the various active and passive fire safety systems in accordance with the relevant design and installation Australian Standards and in accordance with the requirements listed in this report.

16.2 Fire Safety Measures

16.2.1 Fire Resistance and Type of Construction

1. Building elements throughout shall be constructed in accordance with the minimum Fire Resistance Level's (FRL's) commensurate with Type C fire-resisting construction; and
2. Separation of equipment shall be in strict accordance with Clause C2.12 from Volume One of the NCC; and
3. Any electrical substations within the building shall be separated from any other part of the building as required by Clause C2.13 from Volume One of the NCC; and
4. As required, building materials, components and structures shall be suitably tested and approved to achieve the test criteria consistent with AS1530.1:1994 in order to satisfy the DtS provisions of the NCC and/or AS1530.4:2014. All building elements which require an FRL shall be designed, prefabricated and installed in accordance with the tested and approved prototype; and
5. As required, building elements and passive systems (requiring an FRL) shall be suitably tested to meet the test criteria consistent with the minimum requirements prescribed by the DtS provisions of the NCC and/or AS1530.4:2014. All building elements which require an FRL shall be designed, prefabricated and installed in accordance with the tested and approved prototype; and
6. All parts of the building must be constructed in an appropriate manner using materials that are fit for purpose as well as being provided with evidence of suitability with respect to fire resistance and fire hazard properties to the satisfaction of the building certifier; and
7. All building lining materials and assemblies, both internal and external are required to meet the minimum fire hazard properties in Clause C1.10 and Specification C1.10 from Volume One of the NCC; and
8. Should any openings and/or penetrations be proposed, the FRL of the penetrating element shall be reinstated commensurate with the FRL required for the building element. Appropriately tested fire stopping protection methods shall be proposed to the openings/penetrations; and
9. To permit the non-loadbearing super awnings located along the western portion of the building form part of the external wall to be located within 3.0m from the title boundary without the required FRL specified under Table 5 of Specification C1.1. The identified super awnings shall be designed and constructed utilising materials and building elements deemed non-combustible when tested to AS1530.1:1994 or as per BCA Clause C1.12; and
    a. Permit the openings associated with the super awnings to be located within 3.0m from the title boundary; and
    b. Further to the above, the perimeter vehicular access road on the reverse side of the title boundary achieves a minimum clear width of 6.0m; and
    c. The non-loadbearing super awnings is sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 to 'Ordinary Hazard 3' classification unless otherwise Storage Sprinklers are proposed.

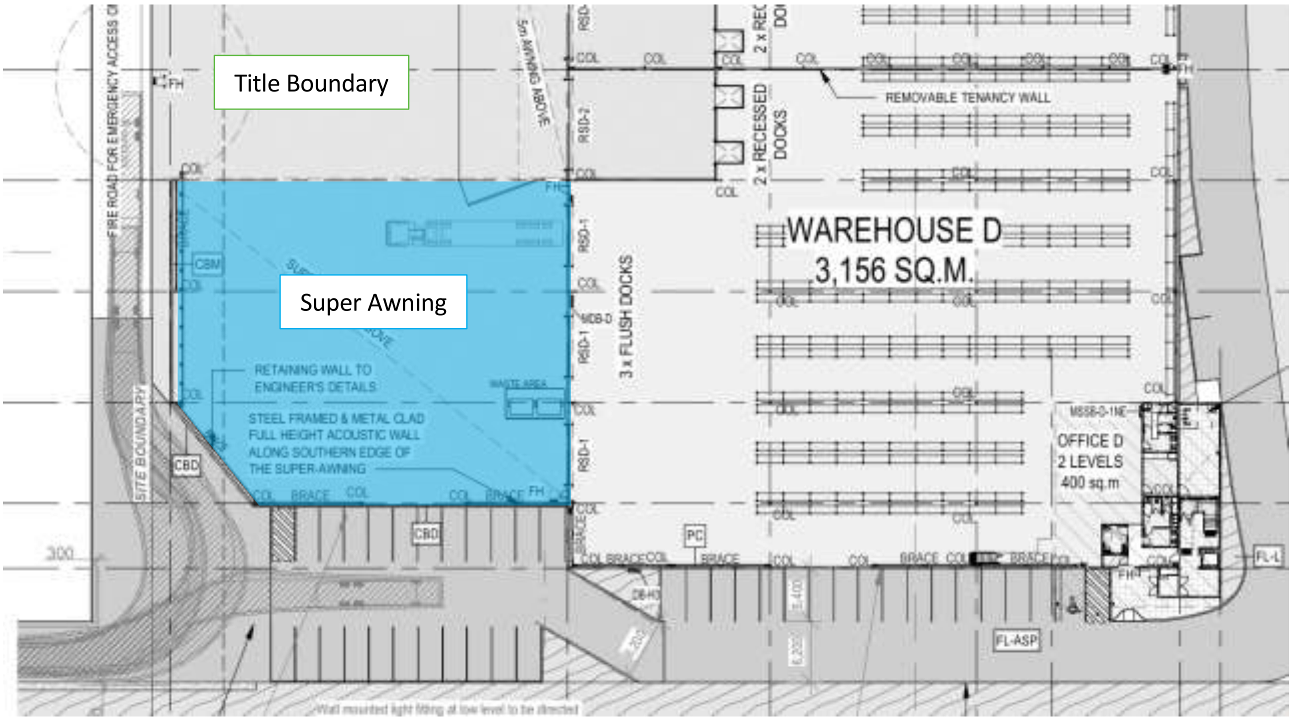


Figure 16.1: Location of super awning and the 6.0m wide perimeter vehicular access road on the reverse side of the title boundary

16.2.2 Occupant Egress Provisions

1. Egress provisions must comply with Part D from Volume Once of the NCC serving the Class 7b warehouse storage portions with the exception of the following:

   Warehouse A

   a. To permit the distance of travel to designated exits of up to 45m in lieu of 40m; and
   b. To permit the distance of travel between alternative exits of up to 85m in lieu of 60m.

   Warehouse B

   c. To permit the distance of travel between alternative exits of up to 66m in lieu of 60m.

   Warehouse C

   d. To permit the distance of travel between alternative exits of up to 63m in lieu of 60m.

   Warehouse D

   e. To permit the distance of travel between alternative exits of up to 63m in lieu of 60m.

2. Egress provisions must comply with Part D from Volume Once of the NCC serving the Class 5 office portions with the exception of the following:

   Office A

   a. To permit the distance of travel to designated exits of up to 30m in lieu of 20m.

   Office B

   b. To permit the distance of travel to designated exits of up to 30m in lieu of 20m.

   Office C

   c. To permit the distance of travel to designated exits of up to 30m in lieu of 20m.

3. All emergency exit doors which may be locked due to security requirements are to open on General Fire Alarm (GFA) and/or power failure.

16.2.3 Fire Services and Equipment

1. The entire building shall be provided with automatic fire sprinkler protection in accordance with AS 2118.1:2017. The sprinkler system shall be as follows:

   a. The Class 5 office portion of the subject building is to be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 appropriate to 'Light Hazard' classification; and

   b. The Class 7b warehouse portion of the subject building is to be sprinkler protected with the installation of K22 Storage Sprinkler or equivalent incorporating 'fast response' type heads. The activation temperature of Storage sprinkler heads shall be no more than 101°C; and
   c. Covered awnings forming part of the Class 7b portion of the subject building shall be sprinkler protected as per Specification E1.5 from Volume One of the NCC and AS2118.1:2017 to 'Ordinary Hazard 3' classification unless otherwise Storage Sprinklers are proposed; and
2. Where required, the Storage Sprinkler system shall comply with the Factory Mutual (FM Global) Property Loss Prevention Data Sheet 2-0, "Installation Guidelines for Automatic Sprinklers" and Property Loss Prevention Data Sheet 8-9, "Storage of Class 1, 2, 3, 4 and Plastic Commodities." The design and installation of the Storage Sprinkler system shall be in strict accordance with the building geometry/height, achieve required minimum clearance, commodity/storage layout/height & hydraulic pressure/flow requirements; and
3. Permit the sprinkler booster assembly and pump room are not be located adjacent to the principal vehicular entry, at the site boundary and not within direct line of sight of the main entry to the building:
   a. Provide site wide block plans which can be readily seen by FRNSW upon arrival to the site from Johnston Crescent. The block plans shall be weatherproof engraved A1 size illustrating all buildings onsite as well as key fire services (incl. fire hydrant booster location, fixed onsite fire pump sets, sprinkler booster assembly, main FIP location, static fire water tanks, vehicular access road etc.); and
4. The automatic fire sprinkler system must be interconnected to the Building Occupant Warning System (BOWS serving all tenancies within the subject building); and
5. The Building Occupant Warning System (BOWS) shall actuate upon activation of the automatic sprinkler system. The BOWS shall initiate a General Fire Alarm (GFA) throughout the building and hence achieve sound pressure levels in accord with AS1670.1:2018; and
6. Smoke detection shall be provided within the office portions only in accordance with Specification E2.2b and AS1670.1:2018 designed and installed on a spacing of no more than 15m x 15m which shall activate the BOWS throughout; and
   a. Each enclosure within the office portion shall be provided with no less than one (1) detector. This requirement does not apply to enclosures which contain a shower; and
7. The main Fire Indicator Panel (FIP) shall be located within the main entry of Office Warehouse A; and
8. Installations activating the BOWS shall also be connected to a fire alarm monitoring system connected to a fire station or fire station despatch centre in accordance with AS1670.3:2018; and
9. Omit the requirement to provide automatic smoke exhaust system and associated smoke baffle and automatic smoke detection system throughout the building; and
10. The building shall be provided with smoke clearance system, to the degree necessary, to allow a degree of smoke and hot gas venting from the warehouse portions of the building. In this instance, the smoke clearance system shall can be achieved via a manually operated smoke clearance fan system as per the following:
    a. Manual Operation (dedicated fire mode system for smoke clearance – fire brigade use only); and
       i. Manually operated smoke clearance fan(s) system shall be operable by means of activating a 'toggle switches or push button devices' located at the main Fire Indicator Panel (FIP) location; and
       ii. A single manually operated smoke clearance toggle switches shall be provided for each tenancy; and
       iii. The warehouse shall have the capacity to vent a minimum of one (1) air change per hour throughout each warehouse tenancy; and
       iv. Provide additional signage at each sub-fire indicator panel (SFIP) to notify fire crews of the manual toggle switch configuration is located at the main Fire Indicator Panel (FIP). The signage shall be A4 size, in capital letters no less than 50mm in height, in colour contrasting with the background and stating the following (or similar equivalent):

          "SMOKE CLEARANCE FAN CONTROLS AT THE FIRE INDICATOR PANEL IN MAIN ENTRY OF OFFICE WAREHOUSE A"

       v. Designed and installed in accordance with Specification E2.2b with regards to the componentry such as control gear, wiring and operation temperature (i.e. 200°C for a period of 1 hour); and
       vi. Designed and installed with power supply wiring to the smoke clearance fan infrastructure must comply with AS1668.1:2015; and
    b. Make up air provisions shall be evenly distributed, situated at low level and must have a sufficient area size such that one (1) air change to each tenancy part of the building is achieved. The make-up air provisions may be provided via perforated doors/ RSD's or a combination of both, which must be positioned/located below the smoke layer height. The height of the make-up air openings has been provided by the mechanical engineer; and

i. Where RSD's are proposed to be used for make-up air provisions, the RSD's are required to be hardwired to the FIP and be configured to automatically open when the toggle switches for the smoke clearance system are activated by fire-fighting personnel; and

11. Fire hydrants are to be located and installed in accordance with NCC Clause E1.3 and AS2419.1:2005 with the exception of the following:
    a. Permit the fire hydrant booster assembly to not be within sight of the main entry of the building; and
    b. Permit fire hydrants without the requirement for fire rated shield panels throughout the entire site; and
    c. Permit fire hydrants to be located beneath awning structures and furthermore, be designed to achieve external fire hydrant performance;
    d. Provide additional external 'fall back' hydrant(s) to facilitate operations such that fire-fighters are able to utilise the fire hydrants located beneath the covered awnings (refer to Figure 13.1 for further details). The external 'fall back' fire hydrants are to be located within 60m if the fire hydrants located beneath the covered awnings, be located as close as possible to the perimeter vehicular access location and furthermore are to be design and installed to achieve attack fire hydrant performance; and
    e. Permit fire hydrants coverage to be calculated based on Clause 3.5.3.3(b) of AS2419.1:2017, where the building parts receiving coverage are within 70m of the external fire hydrants.
12. The fire hydrant pump room is deemed to be located internal to the building. Therefore, the requirements for the pump room must strictly be in accordance with Clause 6.4.2 from aS2419.1:2005 with respect to the bounding construction of the pump room enclosure and location of doorways leading to open space; and
13. Each fire hydrant outlet shall be provided with a localised block plan (A3 minimum & weather fade resistant) to pictorially and numerically illustrate the next available alternative hydrant outlets; and
14. Any electrical substation(s) and/or Main Switch Board(s) (MSB) proposed for the site shall be situated no less than 10m from the fire hydrant booster assembly; and
15. The fire hydrants in the proposed fire hydrant system are to be accessible for use by Fire & Rescue NSW (i.e. clear paths of travel); and
16. All on-site fire hydrants are to be fitted with Storz hose couplings which comply with Clause 7.1 of AS2419.1:2005. This clause states in part "hose couples shall be compatible with those used by the fire brigade serving the area". Storz hermaphrodite fire hose couplings must be fitted to all fire hydrants and the fire hydrant booster assembly connections as required by Appendix E of AS2419.1:2005. The Storz fittings must be manufactured to DIN 14303, aluminium alloy delivery couplings, in accordance with Appendix A of AS2419.2-1994. Blank caps must be provided in accordance with Clause 2.8 of AS2419.2-1994; and
17. Block plans are to be provided at the main Fire Indicator Panel (FIP) and all sub-fire indicator panels (SIP's), fire hydrant booster assembly and sprinkler booster assembly in accordance with the FRNSW Fire Safety Guideline – Emergency Services Information Package and Tactical Fire Plans (Version 02, dated 07/01/2019); and
18. Fire hose reel system shall be designed and installed in accordance with Clause E1.4 from Volume Once of the NCC and AS2441:2005; and
19. Portable fire extinguishers shall be selected and mounted in accordance with Clause E1.6 from Volume One of the NCC and AS2444:2001; and
20. Exit signs and directional exit signs are to be installed throughout all buildings in accordance with Clauses E4.5, E4.6 and E4.8 from Volume One of the BCA and AS2293.1:2018 with the exception that the mounting heights of exit signage within the warehouse portions of the buildings. The directional and non-directional exit signs are to be "JUMBO" signs and furthermore, shall be mounted 5.5m above the finished floor level measured to the top of the exit sign within the warehouse portion only in lieu of 2.7m as required by the prescriptive provisions from Volume One of the BCA; and
21. Exit signs and directional exit signs within the Class 5 office areas are to be designed in accordance with Clauses E4.5, E4.6 and E4.8 from Volume One of the BCA and AS2293.1:2018.

16.2.4 Storage and Handling of Dangerous Goods

1. The client has not advised that any dangerous goods will be handled and situated within the development; and
2. Should the storage and handling of dangerous goods be proposed at any point in the future, this fire engineering documentation would be required to be re-assessed by a competent fire safety engineer.

16.2.5 Vehicular Access and Open Space Provisions

1. Perimeter vehicular access shall be provided in accordance with Clause C2.3 inter alia Clause C2.4, with the exception of the following:
    a. The perimeter vehicular access is located more than 18m away from the external wall of the building (Warehouse A, B, C and D) due to the recess docks (i.e. up to 45m); and

b. Any perimeter fence gates (and gates forming part of the vehicular access) that are proposed to be locked are required to be fitted with suitable conventional padlocks to enable fire-fighter access with a standard key (i.e. 003 key locks). Alternatively, non-conventional padlocks are permitted provided access keys are provided to Fire & Rescue New South Wales (FRNSW) responding fire station stations.

16.2.6 Management in Use Requirements:

1. Maintain paths of travel to an egress, stair entrances, pedestrian doorways and thoroughfares free of static storage and combustible materials at all times; and
2. The client has advised that there shall be no dangerous goods stored within the warehouses; and
3. Smoking shall not be permitted within the building; and
4. All fire safety measures and Management in Use requirements shall be incorporated into an Essential Services list. All fire safety measures shall be maintained in accordance with the requirements of AS1851 (or equivalent maintenance standard) as identified by Scientific Fire Services. Management in Use requirements shall be inspected and logged on an annual basis; and
5. The recommendations forming part of the performance solution shall be identified as part of the Fire Safety Schedule for the subject premises and is to form part of the building's Essential Safety/Services List.

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Appendix A. Architectural Drawings

A.1 Architectural Drawings

Table A.1: Drawings relied upon

Drawing Number	Drawing Name	Date	Revision
200226-AR-204-A001	Lot 204 Site and Facility Plan	07/05/2021	P2
200226-AR-204-A120	Lot 204 Floor Plans (Office A & D)	07/05/2021	P2
200226-AR-204-A121	Lot 204 Floor Plans (Office B & C)	07/05/2021	P2
200226-AR-204-A200	Lot 204 Warehouse Elevations	07/05/2021	P2
200226-AR-204-A201	Lot 204 Warehouse Elevations	07/05/2021	P2
200226-AR-204-A210	Lot 204 Warehouse Sections	07/05/2021	P2
200226-AR-204-A211	Lot 204 Warehouse Sections	07/05/2021	P2

A.2 Fire Services Drawings

Table A.2: Fire Services Drawings relied upon

Drawing Number	Drawing Name	Date	Revision
Fire Detection & BOWS			
FA-001	Fire Detection & BOWS Layout Legend and Symbols	28/06/2021	03
FA-002	Fire Detection & BOWS Layout Warehouse	28/06/2021	03
FA-003	Fire Detection & BOWS Layout Office A & Office D	28/06/2021	03
FA-004	Fire Detection & BOWS Layout Office B & Office c	28/06/2021	03
Fire Sprinkler			
UFS-FS-001	Warehouse Plan North Fire Sprinkler Layout	27/07/2021	04
UFS-FS-002	Warehouse Plan South Fire Sprinkler Layout	27/07/2021	04
UFS-FS-003	Building A & D Office Fire Sprinkler Layout	27/07/2021	04
UFS-FS-004	Building B & C Office Fire Sprinkler Layout	27/07/2021	04
UFS-FS-010	Details Sheet Fire Sprinkler Layout	27/07/2021	04
Fire Hydrant and Fire Hose Reels			
SAP-HD-1401	Hydraulic Services Site Plan	27/07/2021	6
SAP-HD-4101	Hydraulic Services Fire Hydrant Coverage Plan	23/06/2021	4
SAP-HD-4201	Hydraulic Services Fire Hose Reel Coverage Plan	23/06/2021	4
Mechanical			
M-204-1002-01	Mechanical Services Lot 204 Warehouse Roof Plan Sheet 1	28/06/2021	2
M-204-1002-02	Mechanical Services Lot 204 Warehouse Roof Plan Sheet 3	28/06/2021	2
M-204-1002-03	Mechanical Services Lot 204 Warehouse Roof Plan Sheet 4	28/06/2021	2

A.3 Occupant Numbers

From: A Ciecko
Sent: 10/05/2021 4:04:07 PM AEST (GMT +10:00)
To: Eng Khoon Tan, Geoffrey Pearce, Khalid Hourani
Cc: David Mollerstrom, Riley Sampson, Owen Bersenev, Paul Cassimatis, Kon Makrypodis, Metin Tokcan, Aaron Celarc, Parkan Behayeddin, Christopher Boyack, Kenny Leong
Mail Number: MGC-GCOR-000002
Subject: Re: Draft Fire Engineering Brief (FEB) (v1.0) - Lot 204 Horsley Park

Hi Khalid,

As discussed, please find attached a copy of the marked up plans which show items 1 and 2 of the below correspondence.

Please also see below the population numbers based on the amenities provided:

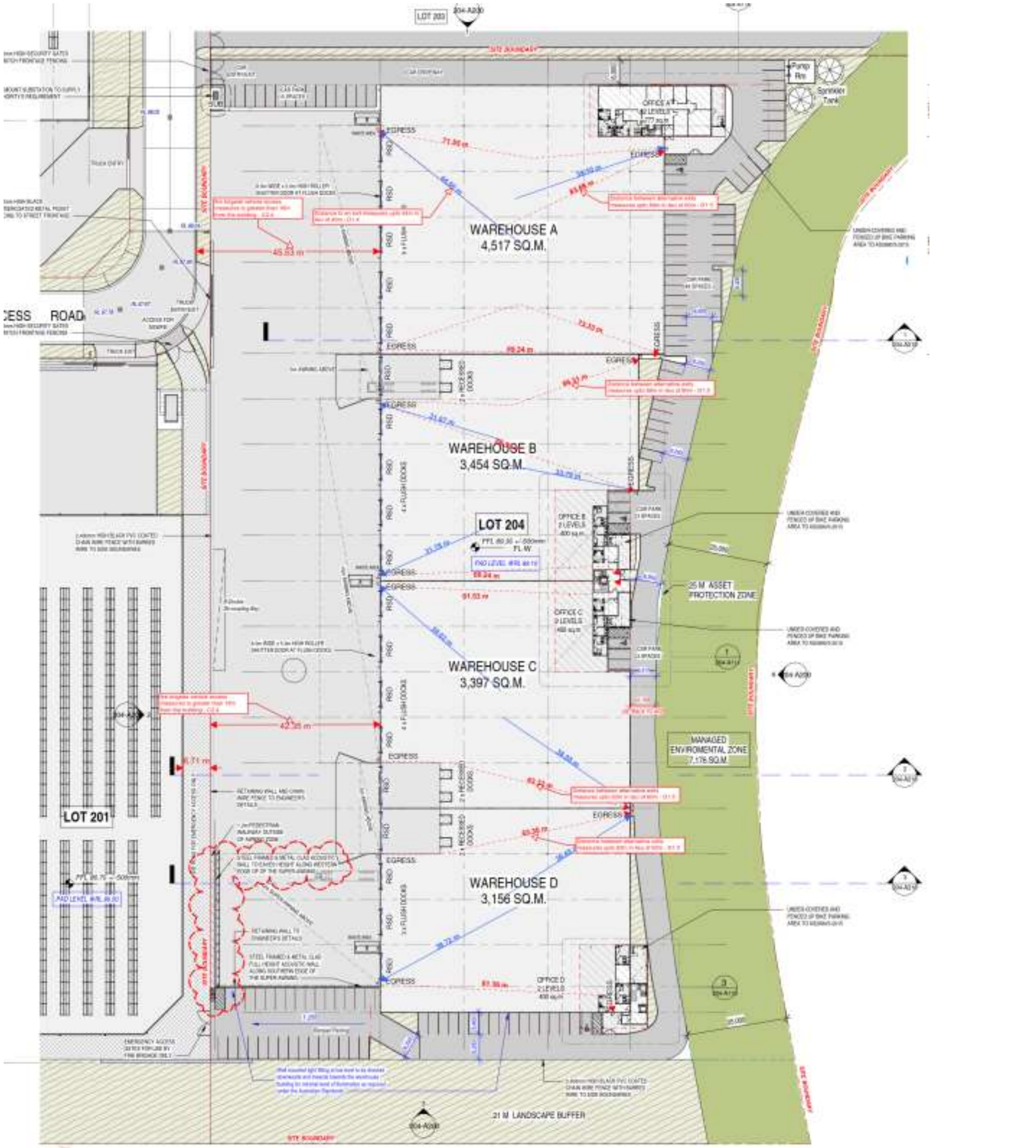
- Warehouse A – 180 people
- Warehouse B – 160 people
- Warehouse C – 160 people
- Warehouse D – 160 people

Any questions please let me know.

Regards,

Alex Ciecko
Building Surveyor

Appendix B. Egress Provisions



Appendix C. Detailed Hazard Analysis

C.1 Class 5 – Office

C.1.1 General

A fire hazard analysis considers the influence of structure, contents and usage on the fire risk. The purpose is to identify those factors which pose risks relevant to the design. The intent of this analysis is to mitigate the risk elements through the design of fire safety features appropriate to the relevant factors of risk.

Offices are an occupancy where primarily administrative work is carried out – “white collar” work such as finance, administration, communication, design and coordination. The Guide to NCC 2019 Volume 1 (ABCB, 2019) clarifies that Class 5 “Office” occupancies includes professional chambers or suites, lawyers' offices, government offices, advertising agencies and accountants' offices. Offices are typically a work environment, and therefore usually occupied only during business working hours. Other entities’ definitions vary slightly. For example, the USA’s National Fire Protection Association defines office buildings as “A facility used for office, professional, or service-type transactions, including but not limited to storage of records and accounts.”

Typically, contents of offices may include significant quantities of paper, electronic devices such as phones and computers, and furniture in the form of desks, tables and chairs, bookcases and filing systems.

While in the past large office buildings were almost universally constructed as multi-room affairs with one or two desks in each separate room, modern practice in larger commercial and government facilities has moved to “open-plan” offices, in which a single large room holds multiple desks separated by short partitions. This tends to allow fire and smoke to spread further, but also makes it easier for evacuating occupants to find the exits.

In all, Building Classification 5 includes a variety of different constructions. There are single stand-alone offices, offices associated with the administration of other facilities (usually as a Class 5 part of a building primarily containing another occupancy), and multistorey offices including some linked by atriums or open stairs. These last are relatively recent design innovations and therefore the influences of such linking of floor levels on fire statistics is not readily discernible.

C.1.2 Principal Sources of Data

Published fire related data is the most useful source of information on risks and hazards related to fire. By comparing the relative incidence and damage of fires in offices to those in other structures, one can obtain a broad appreciation of the hazards and risks in this occupancy.

Statistical data for this analysis has been drawn from a number of sources globally. This section outlines the sources of data consulted, the relevancy of that data to the Class 5 occupancy, and any assumptions or restrictions integral to the data.

Given the general lack of extensive and specific fire incident data for Australia, it is necessary to draw upon data from other sources. In this case, data has been drawn from sources in the United States of America, the United Kingdom, New Zealand and Europe to enable more comprehensive analysis. These data sources are considered relevant because Australian regulations and construction practices are broadly similar to those in these countries. International analysis shows overall rates of fire starts and casualties similar to Australian rates (see Section C.1.5 of this appendix).

In addition, a report analysing Australasian Fire Authority Council data (Arup, 2008) (discussed below under Australian Data) compares Australian fire frequency data to UK data using methods proposed in British Standard BSI PD 7974 Part 7:2003. The result of one of these methods is displayed in Figure C.1. The report concludes based on these analyses that there is reasonable similarity between Australian and UK data.

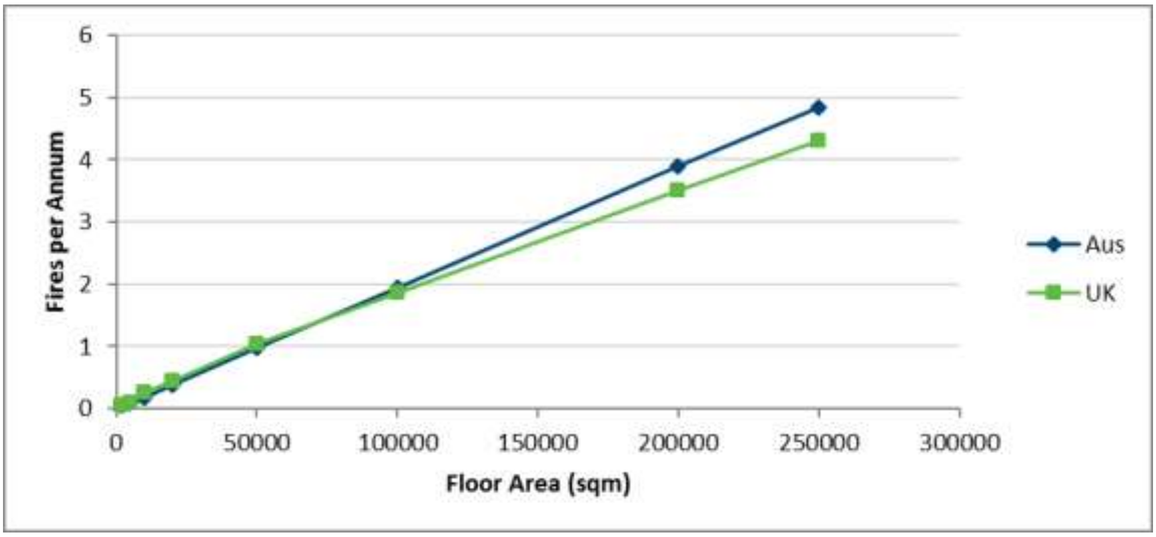


Figure C.1: Australian data compared to UK data for fire frequency in offices.

The principle sources of data used for this hazard analysis of office occupancies include:

C.1.2.1 Australian data:

Australian data is generally not made available by fire brigades, and when available is not divided by occupancy. Thus, data structured usefully for our purposes is infrequently available. Two useful reports are:

- Building Fire Scenarios – An analysis of fire incident statistics (CSIRO, 2000)

This report gives fire data for five years, 1989-1993, averaging 9,760 fires per year. This data was collected by the Australian Fire Incident Reporting Scheme, a nation-wide fire brigade system. It is estimated that only 81-85% of fires that occurred were reported in AFIRS, but the data has not been adjusted to counteract this because that would introduce additional uncertainty. This data corresponds very well to Class 5 buildings, as it is divided by Australian categorisation methods, which changed little over the intervening years. However, the CSIRO data is not displayed by occupancy apart from the statistics for fire frequency, so those are the only statistics useful for this analysis.

- AFAC National Incident Data Base Statistical Assessment – Preliminary Report (Arup, 2008)

In partnership with the Australasian Fire Authorities Council, Arup Fire prepared this report on data in the AFAC's national incident database. The data investigated covers a period of six years between 1998 and 2004, including a total of 62,583 fire incidents. This data corresponds very well to Australian classifications, as it is drawn from Australian sources, however only 5 categories are analysed: Office, Retail, Institutional, Manufacturing and Storage. All other properties are grouped as "other", hence comparison to educational, residential or other classifications is not possible.

C.1.2.2 New Zealand data:

New Zealand can be considered Australia's closest neighbour in terms of culture and regulation. For example, Australia and New Zealand share a number of joint AS/NZ Standards. The New Zealand Fire Service's annual reports do provide statistics divided by occupancy, and so are useful here:

- The New Zealand Fire Service Emergency Incident Statistics 2009-2010 (NZFS, 2010)

This report covers four years of fires, 2005/06-2009/10, totalling 22,572 fires per year on average. Note that the NZ classification system is different to the Australian one and the office class is a narrower group than Australia's Class 5 – the NZ subclass does not include, for example, dentists' offices or veterinary practices. In addition, the NZ data includes non-structure fires such as those on roads or recreational spaces, accounting for the much greater number of fires per year compared to the Australian statistics.

C.1.2.3 United States of America data:

Data sourced from the USA covers the years 2007-2011, but only includes fires reported to municipal fire departments. Data was collected via the U.S.A.'s National Fire Incident Reporting System (used by the fire brigades) and the annual NFPA fire department experience survey, and so this data comes from a fire brigades' viewpoint. Three NFPA reports were referenced for this analysis:

- Structure Fires by Occupancy 2007-2011 (NFPA Fire Analysis and Research Division, 2013)

In this report, the division of occupancies is different from the BCA. Occupancies considered valid in reference to Class 5 are: 'Business Office', 'Bank', 'Veterinary or research', and 'Post office or mailing firm'. These have been added together to create an approximation of Class 5 data.

- US Structure Fires in Office Properties (Campbell, Richard, 2013)

The sample size in this report is an average of 3,340 structure fires in office properties per year over the five-year period. This data relates to all of the different constructions of offices listed above except 'offices associated with other occupancies', but doesn't distinguish between them. Analysis of this data in Section C.1.4 of this appendix uses property damage as an indicator of fire size and therefore to some extent deadliness.

- High-rise Building Fires (Hall, 2009)

This is an older report which covers four years, 2003-2006, with an average of 13,400 high-rise building fires per year. As the title implies, it only deals with high-rise facilities.

C.1.2.4 United Kingdom data:

The United Kingdom's Home Office publishes fire data online in table form, as downloadable Microsoft Excel spreadsheets. The useful table for our purposes is:

- Fire Statistics Table 0301: Fires, fatalities and non-fatal casualties in other buildings by motive and building type, England (Gov.UK, 2016)

This table includes data for 2014/15, which is only 1 year of data. The United Kingdom Home Office has only made available data for England in 2014/15. Previous years' data is available for all of Great Britain, but does not separate Office tenancies from Retail. As a result, the usable data here has a small sample size, and may not be accurate to overall frequencies.

C.1.2.5 European data:

Data has also been drawn from the following studies in Finland:

- Utilisation of Statistics to Assess Fire Risks in Buildings (Tillander, 2004)
- The Ignition Frequency of Structural Fires in Finland 1996-99 (Tillander & Keski-Rahkonen, 2003)

This data was gathered using the Finnish national accident database PRONTO and data on floor areas was provided by Statistics Finland. It covers four years of fires, totalling 2376 fires per year on average. This is roughly one-fourth of the fires per year of the Australian data above, a difference which can be attributed to Finland's lower population, which is approximately one-fourth that of Australia. The frequencies of ignition have been divided by the floor area of each category to adjust for the much greater quantity of residential buildings.

So, while there is limited usable Australian fire statistics available, there are plenty of international sources of data, and these overseas sources are relevant to the Australian built environment, and can be used with care to inform fire engineering and design in Australia.

C.1.3 Fire Loads

The fire load of a space is the density of fuel there, usually expressed in megajoules per square metre. A greater fire load in a space will generally lead to larger, more dangerous fires. Unfortunately, there is no practical way to define or control fuel loads in an office space, and as a result there are no regulations on fuel load levels or furniture construction. Figure C. through Figure C.5 provide an illustration of the possible variety of office arrangements and associated fuel loads. There will be offices with much lesser fuel loads and potentially some with greater.

Figure C.2: A typical desk in an older closed-plan office.

Figure C.3: Open-plan office in a large hall.

Figure C.4: Open-plan office with a fuel load of electronics.

Figure C.5: Open-plan office with significant paper storage.

To establish a representative quantity for an Office fire load, a number of sources have been examined:

Table C.1: Fire Loads from various sources

Category	Fire Load (MJ/m^2)	Standard Deviation	Source and Notes
Office	420	126	EN 1991-1-2 (2002) Referenced in SFPE Handbook (SFPE, 2016) No permanent load included – only contents
Office	827*	-	(Proe & Bennets, 1994) a fire test
Office	978-1269*	-	(Thomas, et al., 1992) A fire test, fire load noted as “in very high range”
Offices	1862	2361	(Claret & Andrade, 2007) Survey of Historic buildings, with minimal fire resisting construction and often primarily timber construction.
Authority or Bank Office	800		(England et al. 2000) ‘Fire resistant barriers and structures’, reproduced in the IFEG 2005
Dentist or Doctor’s Office	200		
High-rise Office Building	800		
Business Office	800		
Engineering Office	600		
Machinery Manufacture Office	300		
Post Office	400		
Offices in Canada	557	286	(Khorasani, et al., 2014) review of a 2011 Canadian survey
Offices in India	348	262	(Khorasani, et al., 2014) review of a 1993 Indian survey
Offices in Europe	300-900	-	(Khorasani, et al., 2014) review of a 2005 European survey
USA Government Offices	641	641	(Khorasani, et al., 2014)

Category	Fire Load (MJ/m^2)	Standard Deviation	Source and Notes
USA Commercial Offices	720	562	
European data	330-420	330-400	(CIB, 1986)

** Value given in kg wood equivalent. Conversion to MJ/m^2 by multiplying by 18.8 MJ/kg, the average of all woods' net heats of combustion given in the SFPE Handbook (SFPE, 2016), Appendix 3, Table A.32, p3449.*

As can be seen in Table C.1, the overall fire load can vary significantly, depending in part on the storage and archival practices in place. For example, some offices would maintain only electronic archives, while others would store past files in hard copy.

It is also useful to consider the distribution of materials involved in fuel loads. Office fuel load distribution data used in Table C.2 breaks down Engineering and Clerical desk units (Kakegawa, 2003) and overall moveable fuel loads in offices (Caro & Milke, 1995).

Table C.2: Composition of Office Fuel Loads

Item	Mass	Given Materials
Engineering Desk Unit	**(kg)**	
desk	42.1	melamine resin, board, metal frame
desk wagon	23.9	polystyrene, ABS resin, metal frame
chair	11.1	polyurethane foam
telephone	0.7	
rubbish bin	0.6	polypropylene, paper
desktop computer	11	
desk partition	8	paper, wood, metal frame
paper files	125	paper
file box	30	paper
total	**240.7kg**	
Clerical Desk Unit	**(kg)**	
desk	35.4	melamine resin, board, metal frame
desk wagon	23.9	polystyrene, ABS resin, metal frame
chair	13.9	polyurethane foam, plastic
telephone	0.7	
rubbish bin	0.6	polypropylene, paper
laptop computer	3	
desk partition	7	paper, wood, metal frame
paper files	50	paper
file box	15	paper
total	**145.8kg**	
Average Total Movable Fuel Loads	**(lb)**	
Papers/Books	2742	paper
computer equipment	332	
furniture	136	
Partitions	854	
total	**3732lb**	

We can see that a significant majority of most office fuel loads will be in the form of paper or other cellulosic material (such as wood), but there are significant portions of plastics. Particular note should be paid to expanded plastic foams, as these ignite easily and burn very quickly. It should be noted that in the years since these studies, there may well have been a move toward more electronic (so-called "paperless") offices, which would reduce the quantity of cellulosic materials relative to plastics and electronics.

While it is largely impossible to control or regulate fire loads in office properties, most studies find a mean fuel load in the range of 300-700 MJ/m^2. Most of the fuel load in offices is in the form of paper or wood, but there are significant quantities of plastics and electronics present as well.

C.1.4 Ignition Sources

Fires have to start from something – they don't spontaneously appear. Potential sources of fire, which are therefore sources of risk, include items which produce heat or sparks, and are termed 'ignition sources'. Ignition sources must be considered because they determine where and how fires can start, thereby informing the location of design fires and providing direction to effective preventative measures. The most effective measure to reduce fire risk is to reduce the frequency of fires by controlling ignition sources.

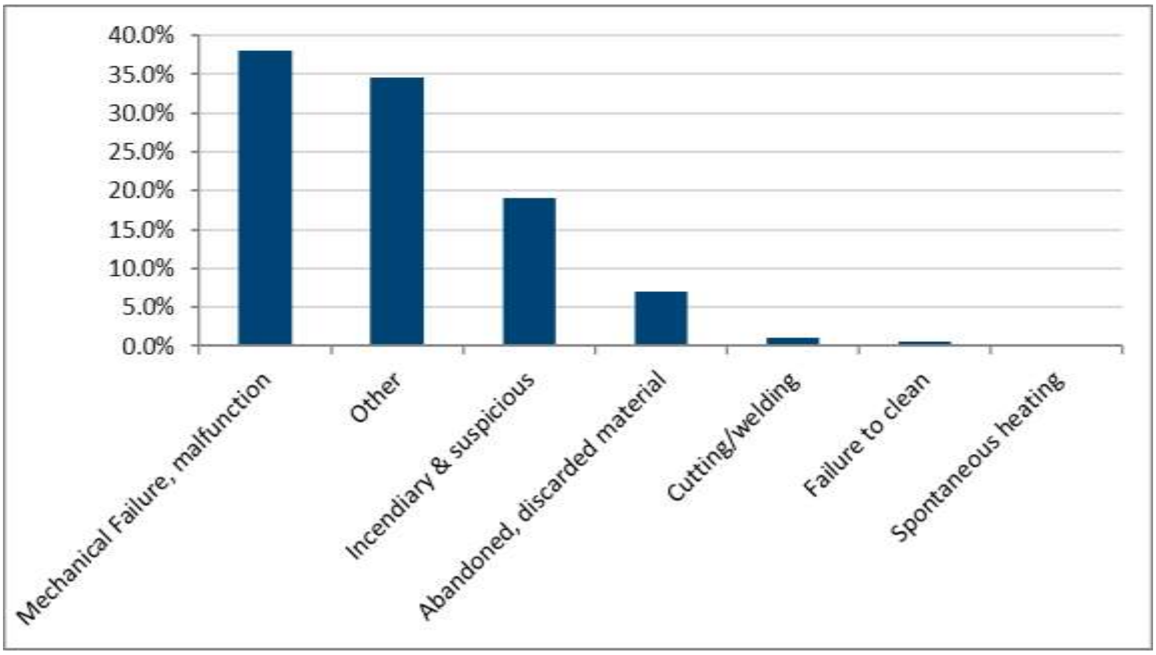


Figure C.6: Office fires in Australia by ignition sources 1998-2004 (Arup, 2008)

Australian data in Figure C.6 shows that malfunctions are the most common source of ignition. In addition, 62% of that category was related to short circuits and electrical malfunctions.

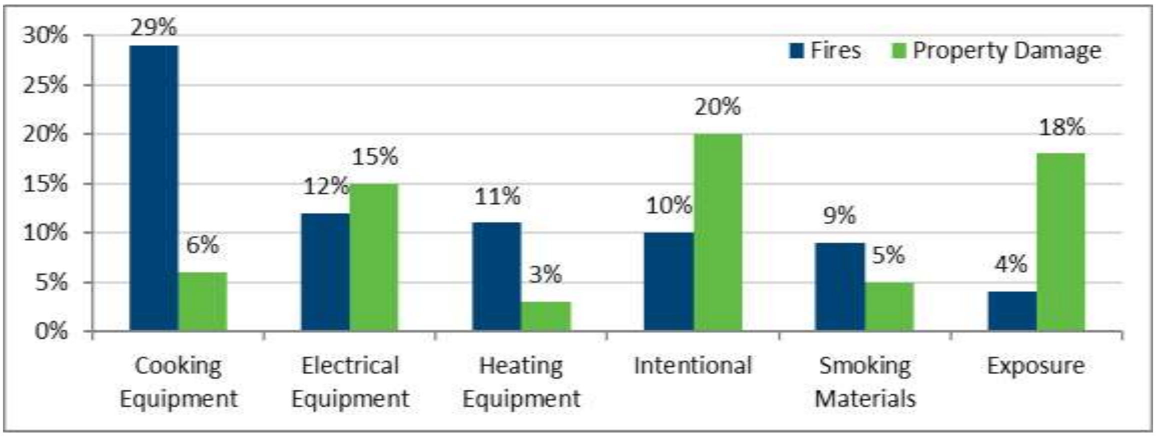


Figure C.7: Office fires and property damage in USA by 6 most common ignition sources 2007-2011 (Campbell, Richard, 2013)

NFPA data, as shown in Figure C.7, indicates:

- Cooking equipment fires are the most common, but not the most damaging.
- The most dangerous of these common fires (dangerousness determined by the ratio of their frequency to property damage) are the intentionally lit fires (i.e. arson), and exposure fires, which is the NFIRS term for when a fire spreads from an adjacent property or building.

Additionally, NFPA analysis of fire locations (Campbell, Richard, 2013) indicates that most office fires start in kitchen areas, while more damage is caused by fires starting in office areas proper.

In high-rise offices, cooking equipment and electrical distribution equipment have an even greater share of ignitions, causing 53% and 18% of fires respectively in the period 2003-2006 (compared to only 20% and 13% respectively in non-high-rise offices in the same period). This can be attributed to the reduction of many other ignition sources which simply don't occur with any frequency in high-rise properties, such as smoking materials (smoking being banned within almost all high-rise buildings) and heating equipment (if the high-rise has centralised heating).

The ignition sources that produce the most frequent fires in offices are cooking equipment and, to a lesser extent, electrical equipment. This is even more the case for high-rise offices. The sources that produce the most fire-related property damage are arson and fires in adjacent properties.

C.1.5 Fire Frequency

Available statistics can be used to give an overall indication of the frequency of fire starts in offices, and are especially useful in comparing the relative hazard of offices to other occupancies. This section indicates the overall downward trend of office fires, the beneficial effects of sprinkler systems, modern design and materials, and the low risk of offices relative to other occupancies, as evidenced by data from Australia and other countries.

Figure C.8 shows that the frequency of fires in office properties has been steadily decreasing in recent years. While this is certainly a positive development, it is important to acknowledge that this trend is almost certainly caused by a range of factors. One of those factors is improving fire safety design, so this trend cannot be used to justify reduced fire safety systems.

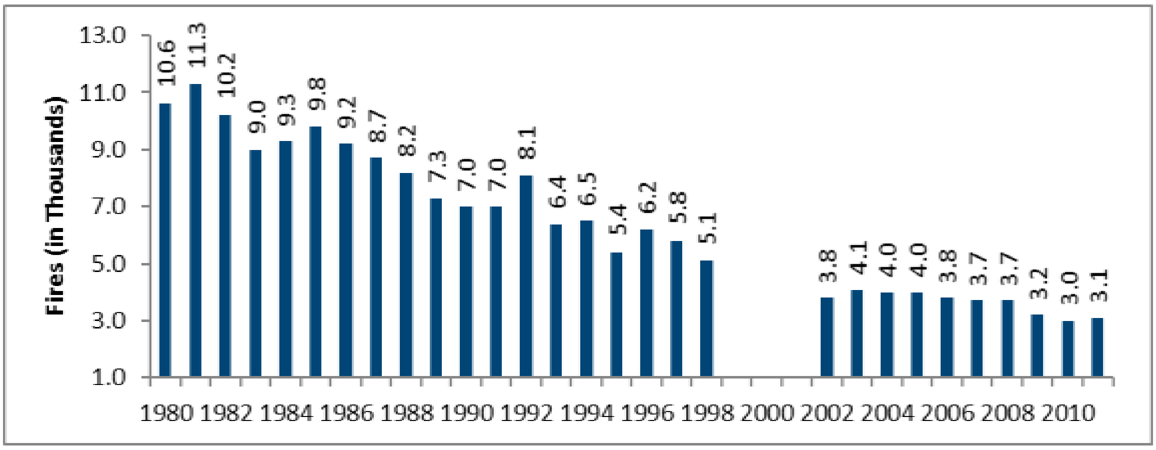


Figure C.8: Office Fires in USA by Year 1980-2011 (Campbell, Richard, 2013)

(1999-2001 was the transition period between versions of NFIRS, and the data from that period is unreliable)

The following figures compare office occupancies to other occupancies in terms of number of fires per year. In each figure, the occupancy containing office properties has been highlighted.

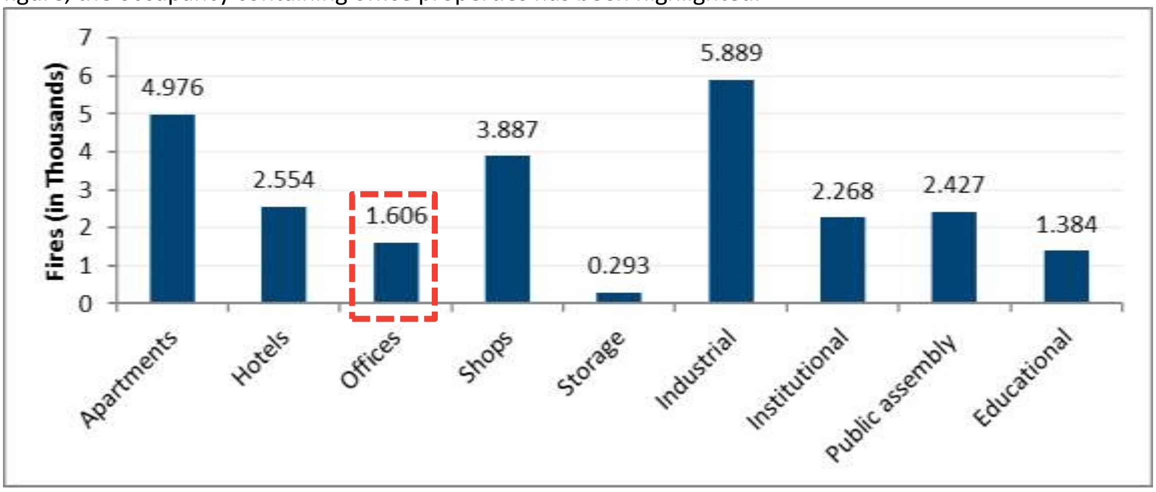


Figure C.9: Fires in Australia by Occupancy 1989-1993 (CSIRO, 2000)

Australian data in Figure C.9 shows that offices contained the third least number of fires from 1989-1993, after educational facilities. More recent data (Figure C.10) indicates a similar outcome.

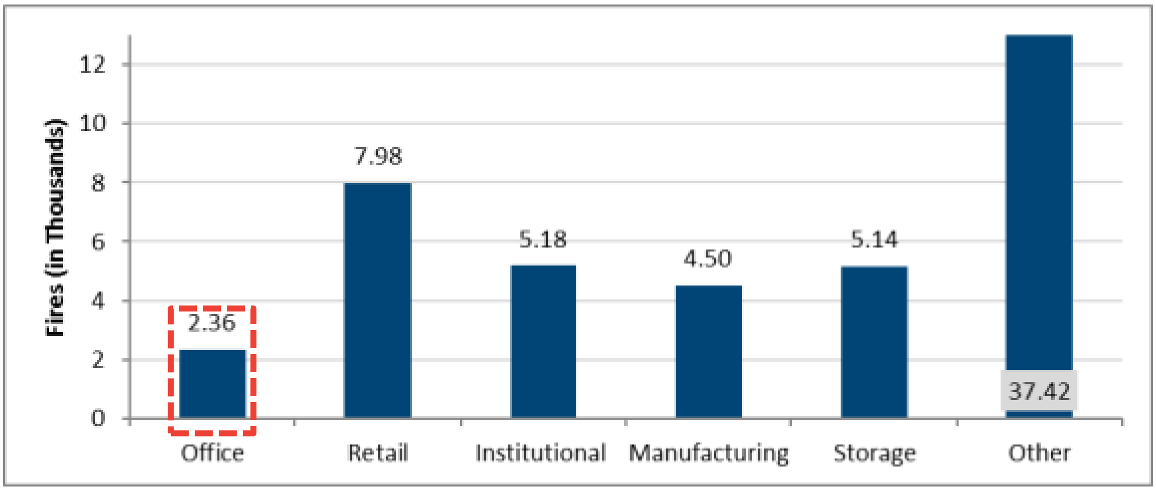


Figure C.10: Fires in Australia by Occupancy 1998-2004 (CSIRO, 2000)

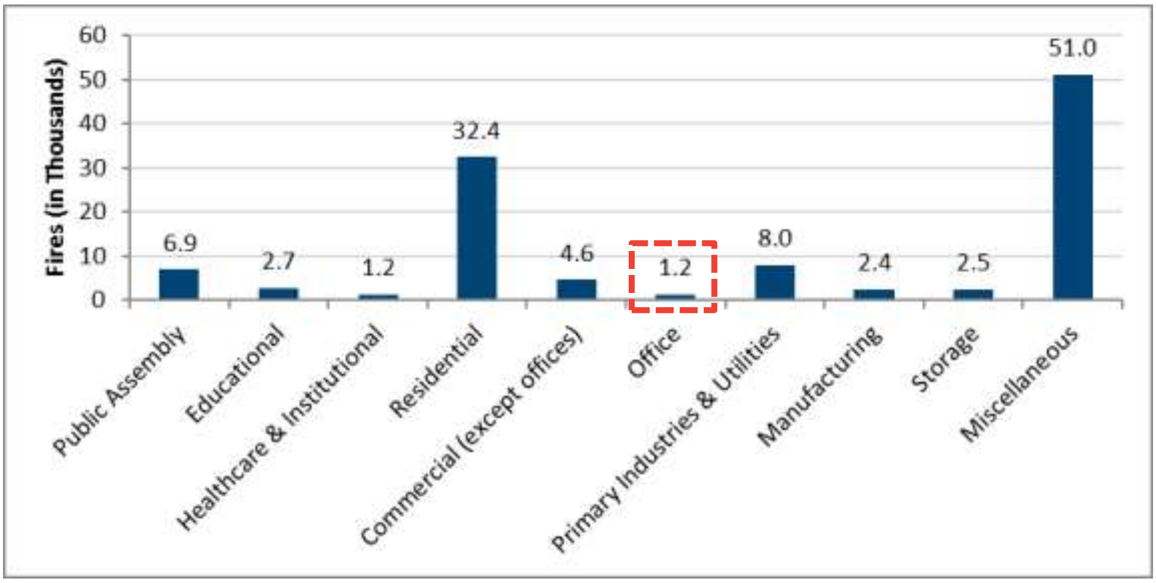


Figure C.11: Fires in New Zealand by Occupancy 2005/06-2009/10 (NZFS, 2010)

Figure C.11 shows that in New Zealand, offices are among the occupancies with the least frequent fires, along with healthcare properties. Note though that the New Zealand system groups offices with commercial properties, so this is a narrower group than Australia's Class 5 occupancy.

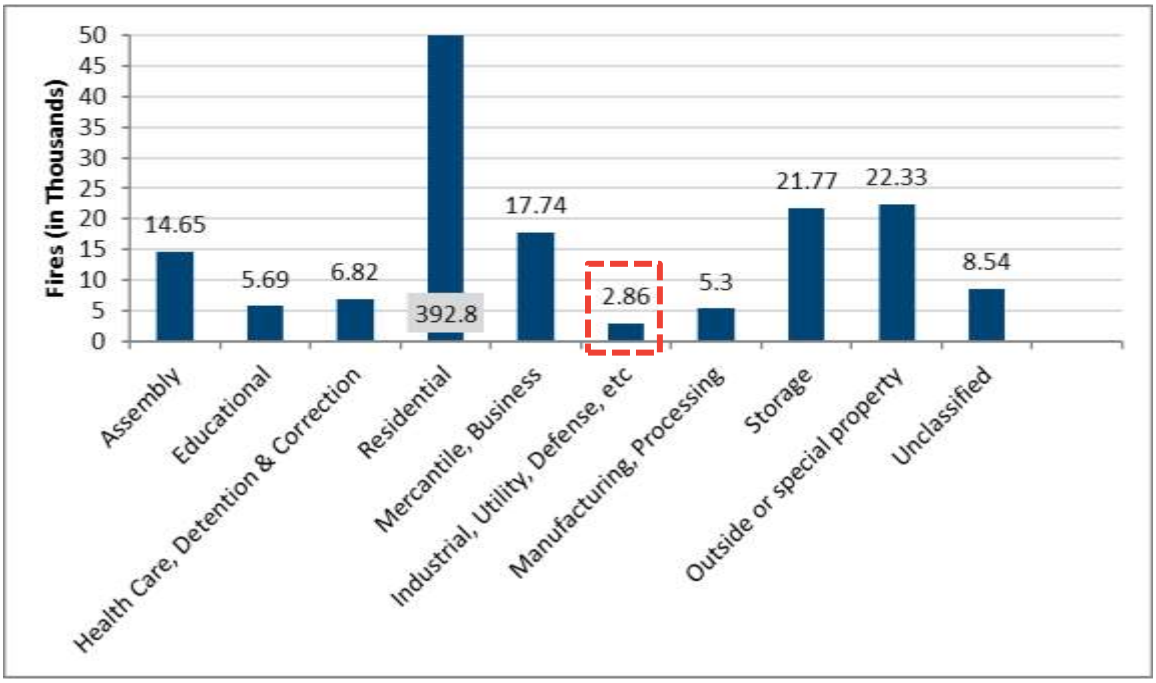


Figure C.12: Fires on Average per Year in USA by Occupancy 2007-2011 (NFPA Fire Analysis and Research Division, 2013)

Referring to Figure C.12, offices in the USA contribute fewer fires than any other classification except the one encompassing Industrial, Utility, Defence, Agriculture and Mining occupancies.

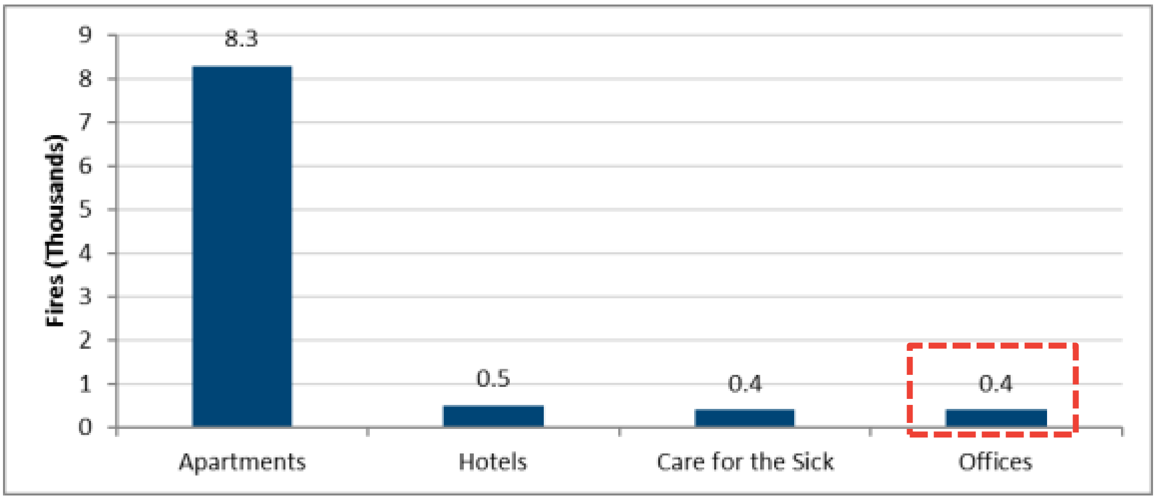


Figure C.13: High-rise Fires Average per Year in USA by Occupancy 2003-2006 (Hall, 2009)

Figure C.13 indicates that in USA High-rise buildings, offices have fewer fires by far than apartments.

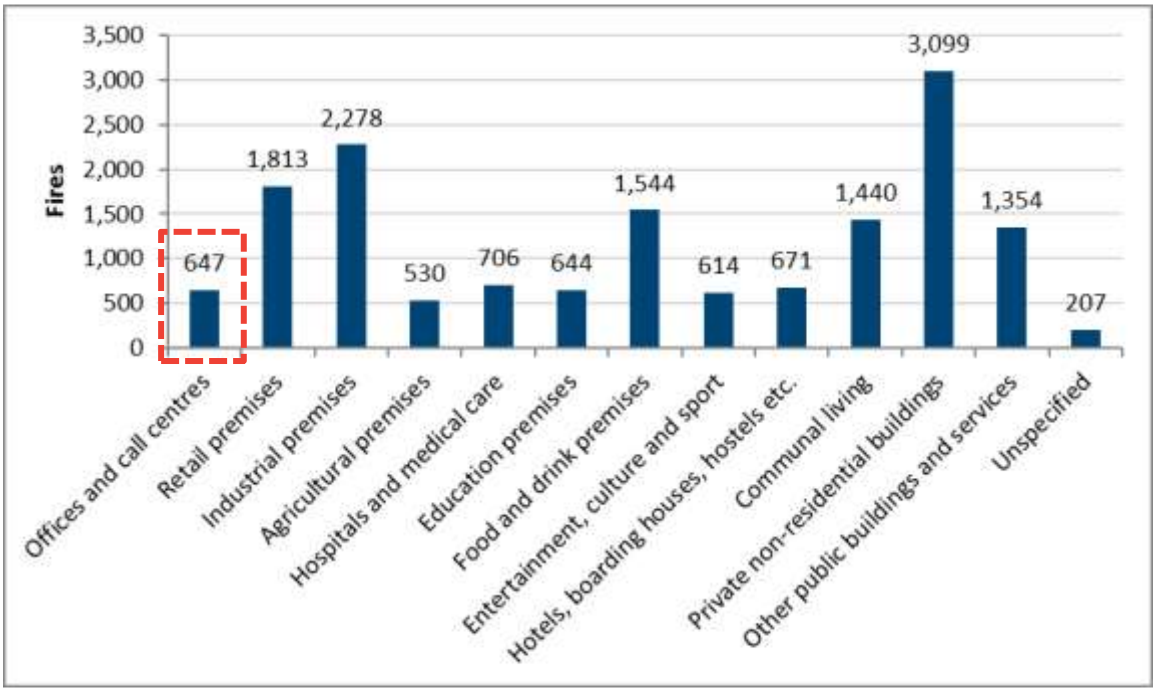


Figure C.14: Fires in England by Occupancy 2014/15

In Figure C.14 we see that offices were among the occupancies with the least frequent fires in England over this year. Offices contained a number of fires roughly equivalent to that found in controlled environments like hospitals or education premises. As mentioned above, the small sample size here reduces the applicability of the data somewhat, but overall comparisons are still useful.

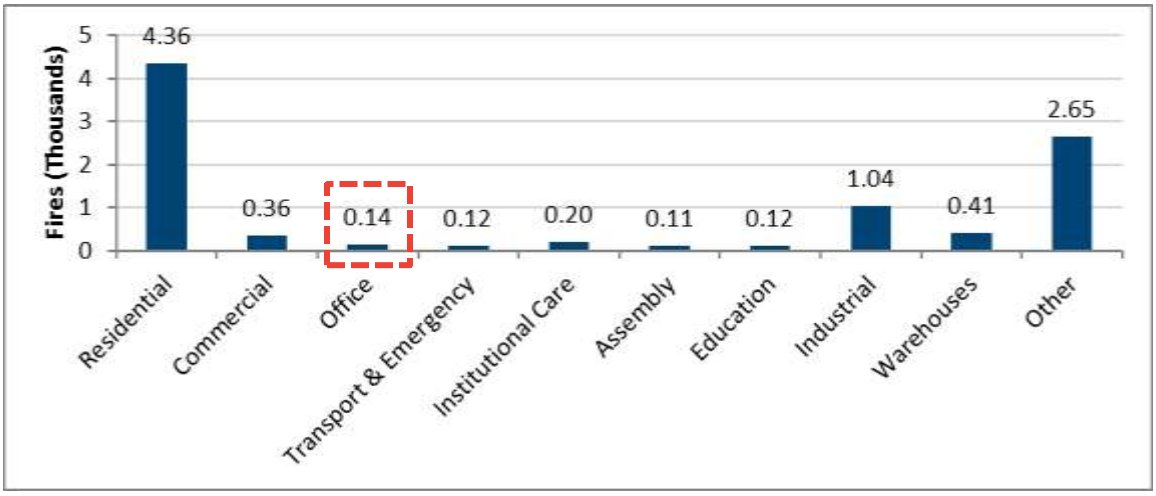


Figure C.15: Structure Fires in Finland by Occupancy 1996-99 (Tillander & Keski-Rahkonen, 2003)

Offices are among the occupancies with the least frequent fires in Finland. This is even clearer when the data is adjusted for floor area:

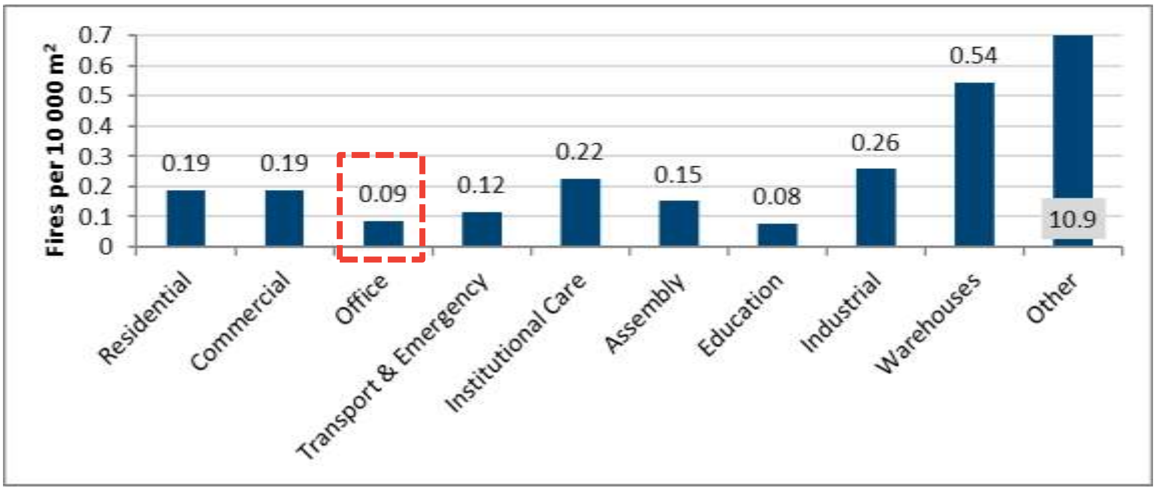


Figure C.16: Structure Fires per unit floor area in Finland by Occupancy 1996-99 (Tillander & Keski-Rahkonen, 2003)

Note that 'other' has a very low floor area, resulting in an ignition rate twenty times the next most frequent. This is largely irrelevant in this case because we are comparing Offices to other occupancies.

Other relevant statistics relating to frequency and spread include:

- While most fires in office properties occur in the middle of the day, most fire damage is caused at night (Campbell, Richard, 2013). This is consistent with the ignition sources above, as many ignition sources, such as cooking equipment, would only be used while the office is staffed (Arup, 2008). The greater damage caused at night can be attributed to the lack of detection and suppression by occupants.
- Average property damage per fire in offices is 46% reduced where wet pipe sprinklers were present (Campbell, Richard, 2013).
- Sprinklers, when they are present and operate, extinguish or prevent the spread of 94% of fires (Arup, 2008). Sprinklers are effective in controlling office fires even when fires are shielded by desks or other shelf-like arrangements (Lougheed, 1997).
- Fires in high-rise offices were half as likely as those in low-rise offices to spread beyond the room of origin, most likely due to the greater use of fire protection systems (including sprinklers) in high-rise buildings (Hall, 2009).

Thus we see that the statistics worldwide indicate that an office building rates relatively low with respect to the risk of fire when compared to buildings of other occupancies. In addition, while (typically non-sprinkler-protected) mid- or low-rise offices are quite low risk, this is even more true of (typically sprinkler-protected) high-rise office properties.

C.1.6 Risk to Life

A pair of very useful statistics in comparing fire risks is the rates of injuries and of fatalities, as they give a good overall impression of the life safety risk of the occupancy, separate from the frequency or intensity of fires. It is important to note, however, that it is still affected by the relative quantities of the different occupancies – there are far more residential buildings than offices, for example, naturally resulting in greater numbers of fires, injuries and fatalities in residential buildings. It can be argued, however, that the smaller amount of time spent in offices as opposed to residential occupancies does make offices naturally safer.

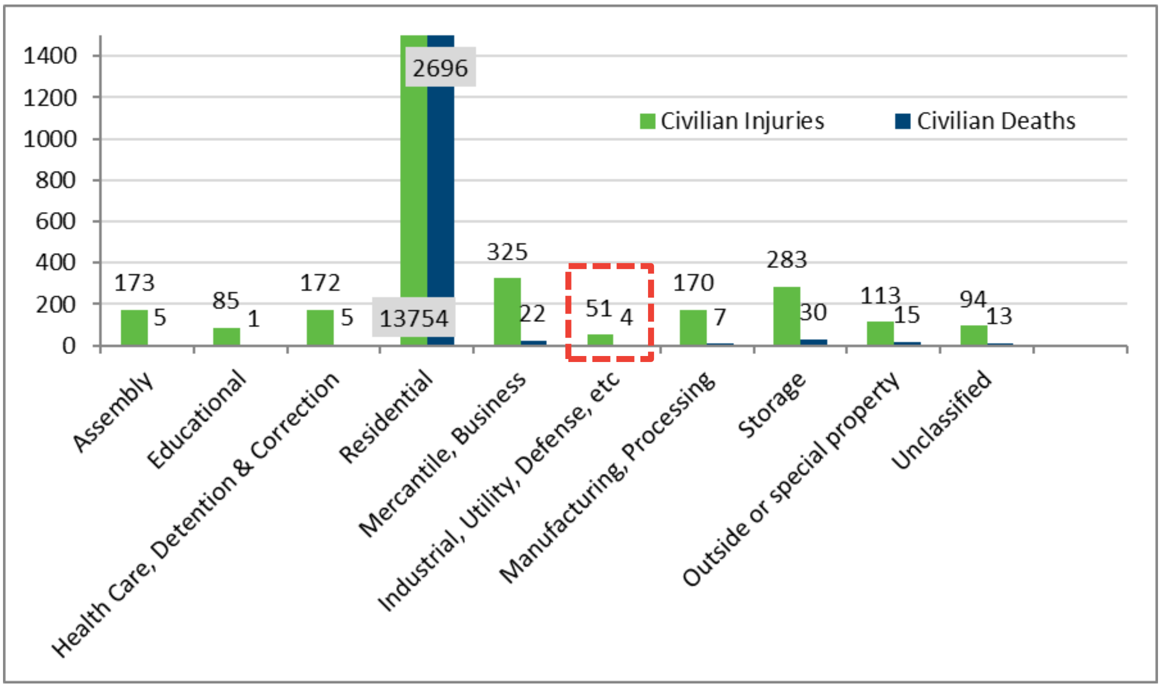


Figure C.17: Average Deaths and Injuries per Year in USA Fires by Occupancy 2007-2011 (NFPA Fire Analysis and Research Division, 2013)

The Office classification is not given as a major occupancy in (NFPA Fire Analysis and Research Division, 2013), however combining the data for occupancies which include the word "office" in their titles, we find that occupancies which in Australia would be Class 5 account for 0.83% of fires, 0.14% of civilian deaths, and 0.31% of civilian injuries.

Furthermore, deaths per thousand reported fires are 62% lower in stores and offices when wet pipe sprinklers are present (Campbell, Richard, 2013).

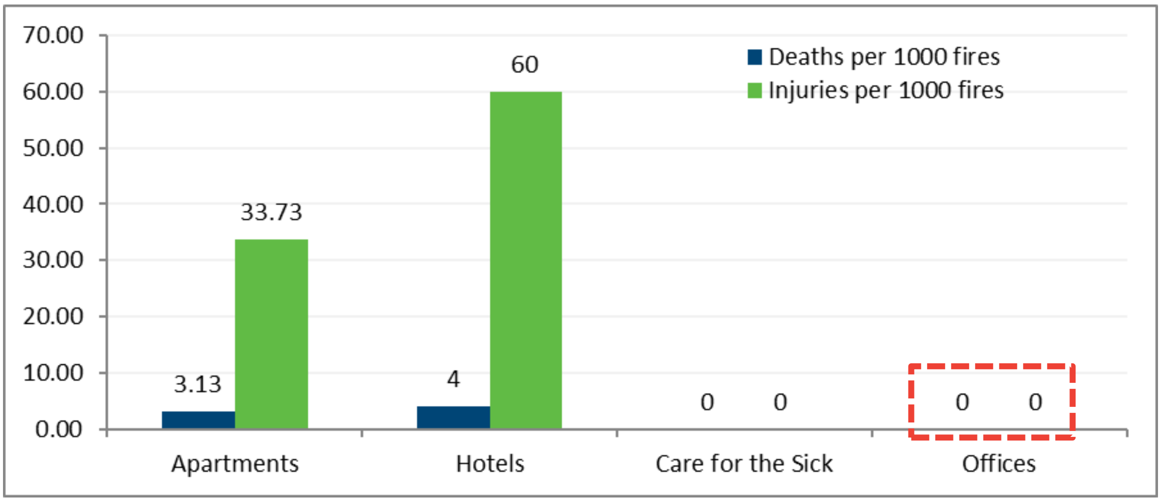


Figure C.18: Average Deaths and Injuries per Year in USA High-rise Fires by Occupancy 2003-2006 (Hall, 2009)

In high-rise buildings specifically, office fires cause far fewer injuries and fatalities than apartments and even hotels. This is likely because the increased fire safety systems installed in high-rise buildings mean that only unaware occupants (asleep or intoxicated or both) are at significant risk inside.

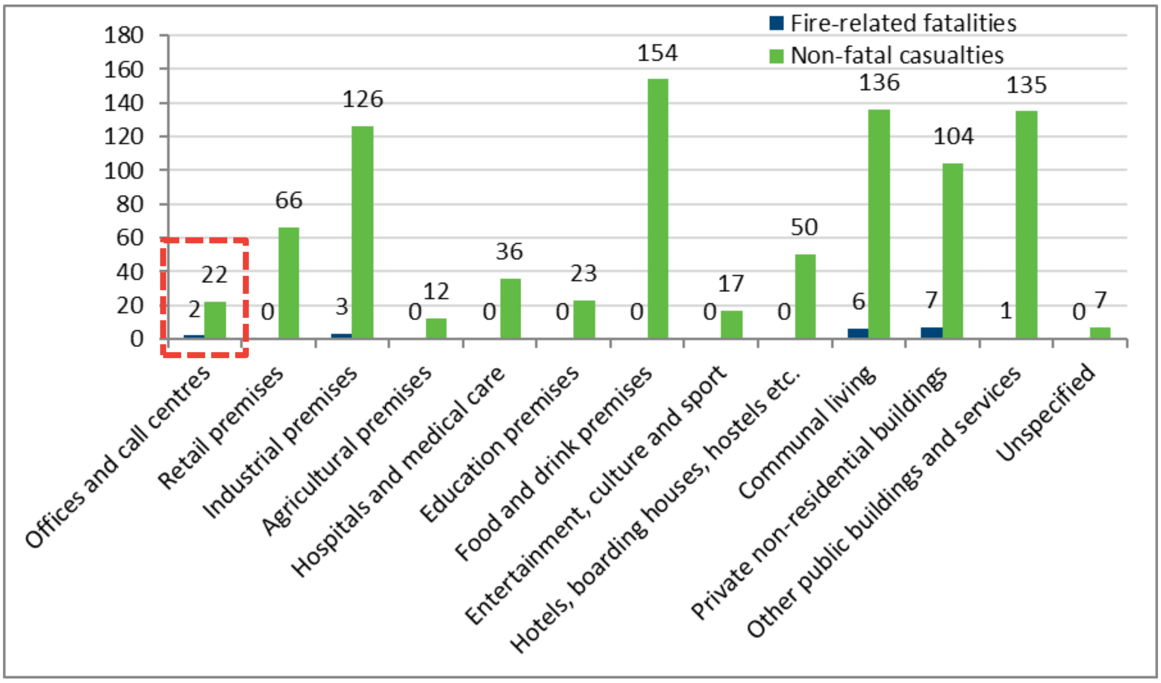


Figure C.19: Fatalities and Injuries in fire by Occupancy, England 2014/15

Offices are among the occupancies with the least frequent fire injuries in England. Unfortunately, the small sample size renders the fatality data here of questionable statistical use, as a single disastrous fire event in a given year can drastically change the number of fatalities in an occupancy for that year.

Thus, we can conclude that offices are an occupancy of low overall fire risk, and in particular have a significantly below-average risk to life from fire events.

C.1.7 Conclusion

While there is limited usable Australian fire statistics available, there are plenty of international sources of data (see Section C.1.2), and these overseas sources are relevant to the Australian built environment, so can be used with care to inform fire engineering and design in Australia. In office occupancies in particular, this data leads to a number of observations:

- While it is largely impossible to define or regulate fire loads in office properties, most studies find a mean fuel load in the range of 300-700 MJ/m^2 (see Table C.1). Most of the fuel load in offices is in the form of paper or wood, but there are significant quantities of plastics and electronics present as well (see Table C.2).
- The ignition sources that produce the most frequent fires in offices are cooking equipment and, to a lesser extent, electrical equipment (see Figure C.7). This is even more the case for high-rise offices. The sources that produce the most fire-related property damage are arson and fires in adjacent properties.
- Statistics worldwide indicate that an office building rates relatively low with respect to the risk of fire when compared to buildings of other occupancies (see Section C.1.5).
- While (typically non-sprinkler-protected) mid- or low-rise offices are quite low risk, this is even more true of (typically sprinkler-protected) high-rise office properties (see Figure C.13).
- Offices are one of the occupancies with the lowest fire fatality risk (see Section C.1.6).
- Automatic sprinkler systems are very effective at reducing the severity of fires in office properties (Lougheed, 1997).

In conclusion, offices are an occupancy of low overall fire risk, and in particular have a significantly below-average risk to life from fire events.

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C.2 Class 7b – Storage

C.2.1 General

A fire hazard analysis considers the influence of structure, contents and usage on the fire risk. The purpose is to identify those factors which pose risks relevant to the design. The intent of this analysis is to mitigate the risk elements through the design of fire safety features appropriate to the relevant factors of risk.

Storage buildings are buildings whose primary purpose is the storage or redistribution of products or materials. The NCC 2019 Volume 1 (ABCB, 2019) specifies that a Class 7b occupancy is "a building for storage, or display of goods or produce for sale by wholesale", the reason for the distinction between wholesale and retail (Class 6) being that buildings which the general public has access to are classified as retail. Other entities' definitions vary slightly. For example, the USA's National Fire Protection Association defines a storage occupancy as "An occupancy used primarily for the storage or sheltering of goods, merchandise, products, or vehicles", differing from the BCA definitions where Class 7b (Storage) is separate from Class 7a (Carparks).

Typically, contents of storage buildings are quite varied, because of the broad variety of goods and products that exist, but there are some common materials, such as wood, cardboard, and plastic, that are often present in packaging.

C.2.2 Principal Sources of Data

Published fire related data is the most useful source of information on risks and hazards related to fire. By comparing the relative incidence and damage of fires in storage structures to those in other structures, one can obtain a broad appreciation of the hazards and risks in this occupancy.

Statistical data for this analysis has been drawn from a number of sources globally. This section outlines the sources of data consulted, the relevancy of that data to the Class 7b occupancy, and any assumptions or restrictions integral to the data.

Given the general lack of extensive and specific fire incident data for Australia, it is necessary to draw upon data from other sources. In this case, data has been drawn from sources in the United States of America, the United Kingdom, New Zealand and Europe to enable more comprehensive analysis. These data sources are considered relevant because Australian regulations and construction practices are broadly similar to those in these countries. International analysis shows overall rates of fire starts and casualties similar to Australian rates (see Section C.1.5 of this appendix).

The principle sources of data used for this hazard analysis of industrial occupancies include:

C.2.2.1 Australian data:

Australian data is generally not made available by fire brigades, and when available is not divided by occupancy. Thus data structured usefully for our purposes is infrequently available. Two useful reports are:

- Building Fire Scenarios – An analysis of fire incident statistics (CSIRO, 2000)

This report gives fire data for five years, 1989-1993, averaging 9,760 fires per year. This data was collected by the Australian Fire Incident Reporting Scheme, a nation-wide fire brigade system. It is estimated that only 81-85% of fires that occurred were reported in AFIRS, but the data has not been adjusted to counteract this because that would introduce additional uncertainty. In addition, a later study (Barnett, 2008) found that 78% of fires go unreported to fire brigades. The data in this report corresponds very well to Class 7b buildings, as it is divided by Australian categorisation methods, which changed little over the intervening years. However, the CSIRO data is not displayed by occupancy apart from the statistics for fire frequency, so those are the only statistics useful for this analysis.

- AFAC National Incident Data Base Statistical Assessment – Preliminary Report (Arup, 2008)

In partnership with the Australasian Fire Authorities Council, Arup Fire prepared this report on data in the AFAC's national incident database. The data investigated covers a period of six years between 1998 and 2004, including a total of 62,583 fire incidents. This data corresponds very well to Australian classifications, as it is drawn from Australian sources, however only 5 categories are analysed: Office, Retail, Institutional, Manufacturing and Storage. All other properties are grouped as "other" so comparison to educational, residential or other classifications is not possible.

C.2.2.2 New Zealand data:

New Zealand can be considered Australia's closest neighbour in terms of culture and regulation. For example, Australia and New Zealand share a number of joint AS/NZ Standards. The New Zealand Fire Service's annual reports do provide statistics divided by occupancy, and so are useful here:

- The New Zealand Fire Service Emergency Incident Statistics 2009-2010 (NZFS, 2010)

This report covers four years of fires, 2005/06-2009/10, totalling 22,572 fires per year on average. Note that the NZ data includes non-structure fires such as those on roads or recreational spaces, accounting for the much greater number of fires per year compared to the Australian statistics.

C.2.2.3 United States of America data:

Data sourced from the USA covers the years 2007-2011, but only includes fires reported to municipal fire departments. Data was collected via the U.S.A.'s National Fire Incident Reporting System (used by the fire brigades) and the annual NFPA fire department experience survey, and so this data comes from a fire brigades' viewpoint. Two NFPA reports were referenced for this analysis:

- Structure Fires by Occupancy 2007-2011 (NFPA Fire Analysis and Research Division, 2013)

In this report the division of occupancies is different from the BCA, so while the Residential classification corresponds well to Class 2 and 3 buildings, direct comparison to specific other classifications is of variable value.

- Structure Fires in Warehouse Properties (Campbell, 2016)

Covers the five years 2009-2013, an estimated 1,210 warehouse fires per year causing averages of 3 civilian fatalities and 19 civilian injuries per year. It is notable that this report includes outside fires in addition to structure fires, but these are very few. Where possible, this analysis has excluded non-structure fires. The NFPA definition of "warehouse" closely matches BCA Classification 7b, because it includes most storage buildings but excludes carparks.

C.2.2.4 European data:

Data has also been drawn from the following studies in Finland:

- Utilisation of Statistics to Assess Fire Risks in Buildings (Tillander, 2004)
- The Ignition Frequency of Structural Fires in Finland 1996-99 (Tillander & Keski-Rahkonen, 2003)

This data was gathered using the Finnish national accident database PRONTO and data on floor areas was provided by Statistics Finland. It covers four years of fires, totalling 2376 fires per year on average. This is roughly one-fourth of the fires per year of the Australian data above, a difference which can be attributed to Finland's lower population, which is approximately one-fourth that of Australia. The frequencies of ignition have been divided by the floor area of each category to adjust for the much greater quantity of residential buildings.

So while there is limited usable Australian fire statistics available, there are plenty of international sources of data, and these overseas sources are relevant to the Australian built environment and can be used with care to inform fire engineering and design in Australia.

C.2.3 Fire Loads

The fire load of a space is the density of fuel there, usually expressed in megajoules per square metre. A greater fire load in a space will generally lead to larger, more dangerous fires. Fuel loads in storage spaces vary widely, largely dependent on the products or materials stored there, and their packaging. There will be storage buildings with much lesser fuel loads than the averages below and some with greater. **Figure C.** through Figure C.23 illustrate some of the many possible fire loads that storage properties can present.

Figure C.20: Some of the fire load in warehouses takes the form of the packaging for the product being stored

Figure C.21: Fire loads can become quite large when warehouses are filled with tall racking

Figure C.22: Fire loads in warehouses are largely determined by the material being stored.

Figure C.23: Fire loads can be greatly increased by poor management or overfilling.

To establish representative quantities for storage fire loads, a number of sources have been examined. Note that fabrication values (*) are not applicable to the storage occupancy, but are presented here for completeness and comparison:

Table C.3: Fire Loads from studies undertaken in Switzerland 1967-69, reproduced in the IFEG 2005

Type of occupancy	Fabrication* [MJ/m²]	Storage [MJ/m²/m]
Adhesive mfg	1000	3400
Animal food preparing, mfg	2000	3300
Artificial flower mfg	300	200
Artificial leather mfg	1000	1700
Artificial silk mfg	300	1100
Barrel mfg, wood	1000	800
Basket ware mfg	300	200
Bed sheeting production	500	1000
Bicycle assembly	200	400
Bitumen preparation	800	3400
Box mfg	1000	600
Broom mfg	700	400
Brush mfg	700	800
Butter mfg	700	4000
Candle mfg	1300	22400
Candy mfg	400	1500
Cane products mfg	400	200
Cardboard box mfg	800	2500
Cardboard mfg	300	4200
Cardboard products mfg	800	2500
Carpet mfg	600	1700
Cast iron foundry	400	800
Celluloid mfg	800	3400

Type of occupancy	Fabrication* [MJ/m²]	Storage [MJ/m²/m]
Cordage plant	300	600
Cork products mfg	500	800
Cosmetic mfg	300	500
Decoration studio	1200	2000
Dry-cell battery	400	600
Edible fat mfg	1000	18900
Fertiliser mfg	200	200
Fireworks mfg	special	2000
Foamed plastics fabrication	3000	2500
Foamed plastics processing	600	800
Hosiery mfg	300	1000
Household appliances, mfg	300	200
Jewellery shop	300	1300
Lacquer mfg	500	2500
Liqueur mfg	400	800
Milk, condensed, mfg	200	9000
Milk, powdered, mfg	200	10500
Oilcloth mfg	700	1300
Oilcloth processing	700	2100
Optical instrument mfg	200	200
Packing material, industry	1600	3000
Paper mfg	200	10000
Paper processing	800	1100

Type of occupancy	Fabrication* [MJ/m²]	Storage [MJ/m²/m]
Parquetry mfg	2000	1200
Perambulator mfg	300	800
Pharmaceuticals, packing	300	800
Pharmaceutical mfg	300	800
Plastic mfg	2000	5900
Plywood mfg	800	2900
Printing, ink mfg	700	3000
Refrigerator mfg	1000	300
Rubber goods mfg	600	5000
Rubber processing	600	5000
Soap mfg	200	4200
Synthetic resin mfg	3400	4200
Telephone apparatus mfg	400	200
Tyre mfg	700	1800
Tobacco products mfg	200	2100
Umbrella mfg	300	400
Veneering	500	2900
Veneer mfg	800	4200
Vinegar mfg	80	100
Waffle mfg	300	1700
Washing agent mfg	300	200
Washing machine mfg	300	40
Watch assembling	300	40
Wax products mfg	1300	2100

As can be seen in Table C.3, the overall fire load can vary significantly, depending largely on the material being stored. The above fire loads vary between 40 MJ/m^2/m (washing machines) and 22400 40 MJ/m^2/m (candles). As expected, flammable material storage spaces have significantly greater fire loads than non-flammable products or materials, and therefore require more effective fire protection systems.

As a result of the large variation in fire loads between different products, it is unreasonable to propose a single ‘representative’ fire load for use in analysis of storage facilities. Instead, a design fire load must be selected for each individual facility based on the specific expected use of the building. This necessitates re-evaluation if the use of the building changes significantly.

Note that storage fire loads here are presented in terms of the height of storage – a 4 m high rack of product will have 4 times the listed fire load. Some modern storage facilities with especially high stacking or Automated Storage and Retrieval Systems (which result in dense fuel loads) would possibly require special fire protection measures.

Fire loads in storage properties are extremely varied, changing based on what product or material is being manufactured or processed, and also on the height of storage. Any fuel load for use in analysis will depend on the specific product and storage arrangements in question.

C.2.4 Ignition Sources

Fires have to start from something – they don’t spontaneously appear. Potential sources of fire, which are therefore sources of risk, include items which produce heat or sparks, and are termed ‘ignition sources’. Ignition sources must be considered because they determine where and how fires can start, thereby informing the location of design fires and providing direction to effective preventative measures. The most effective measure to reduce fire risk is to reduce the frequency of fires by controlling ignition sources.

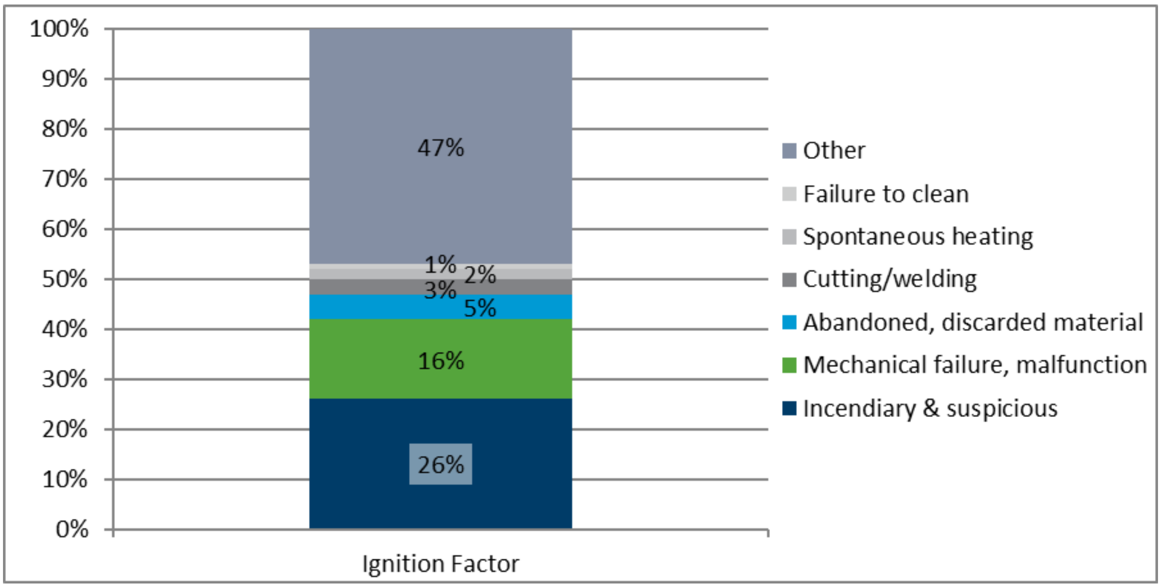

Figure C.24: Storage fires in Australia by ignition factor (ARUP, 2008)

Australian data shows that mechanical failure or malfunction (which includes electrical failures and malfunctions) is the second most common ignition factor, only exceeded by incendiary and suspicious fires (i.e. arson or suspected arson), which account for more than a quarter of all storage fires. Arson is a unique ignition source, because it requires preventative measures more related to security and surveillance rather than maintenance or employee training.

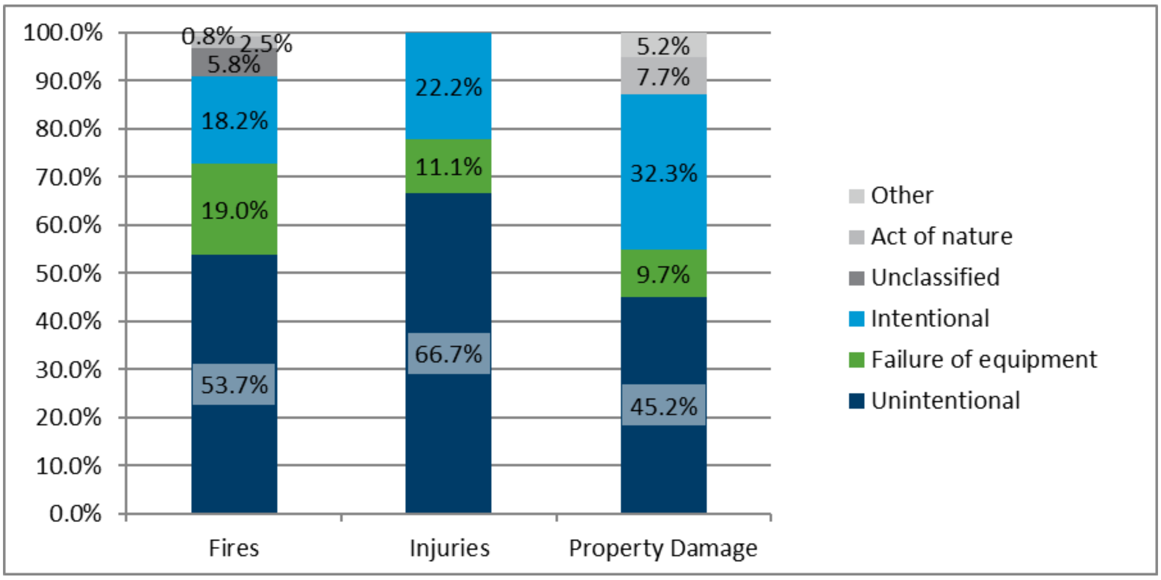

Figure C.25: Warehouse fires, fire injuries, and fire property damage in USA by Cause of Ignition (NFPA, 2013)

In the USA, ignition sources are recorded in three categories: Cause of Ignition, Factors contributing to ignition, and Equipment involved in ignition. Here, cause of ignition shows that a similar proportion of fires are caused by arson as in Australia, though it is notable that equipment failure fires have a similar incidence but significantly lesser likelihood of causing injury or property damage.

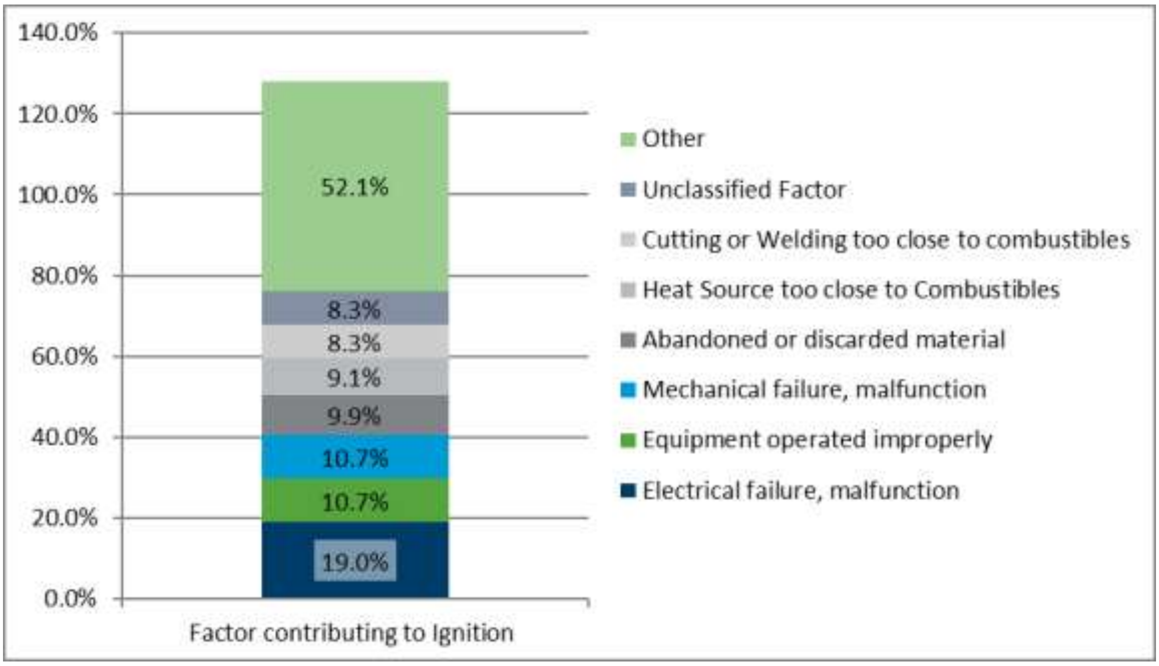

Figure C.26: Warehouse fires in USA by factors contributing to ignition (NFPA, 2013)

The factors contributing to ignition are varied and relatively evenly spread, though it is notable that electrical and mechanical failures are major causes of storage fires in the USA as in Australia. Note that the total here is greater than 100%. This is due to some fires having multiple recorded factors contributing to ignition.

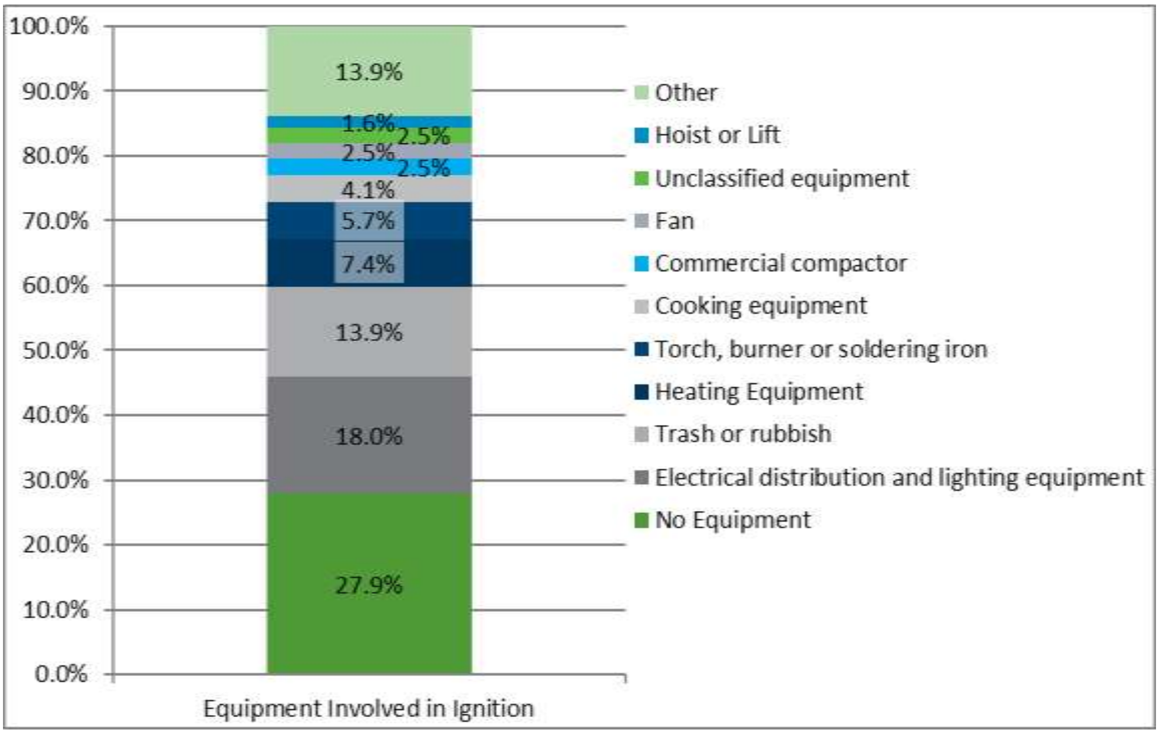

Figure C.27: Warehouse fires in USA by equipment involved in ignition (NFPA, 2013)

When considering equipment specifically, as shown in Figure C.7, there are a wide variety of ignition sources in storage fires. The main sources are Electrical equipment, Trash or rubbish, Heating equipment, and No equipment. This data is drawn from fire brigades identifying "equipment involved in ignition", so "no equipment" is the category which includes fires started by smoking materials, arson, and other non-equipment sources.

The ignition sources that produce the most frequent fires in storage properties are arson, and mechanical and electrical failures. This is consistent with the overall lack of equipment or activity in storage occupancies, and indicates somewhat unique fire prevention needs.

C.2.5 Fire Frequency in Storage Buildings

Available statistics can be used to give an overall indication of the frequency of fire starts in storage buildings, and are especially useful in comparing the relative hazard of residences to other occupancies. This section investigates the frequency of industrial fires compared to other occupancies in a number of countries.

Figure C.8 shows that the frequency of fires in storage properties has been steadily decreasing in recent years. While this is certainly a positive development, it is important to acknowledge that this trend is almost certainly caused by a range of factors. One of those factors is improving fire safety design, so this trend cannot be used to justify reduced fire safety systems.

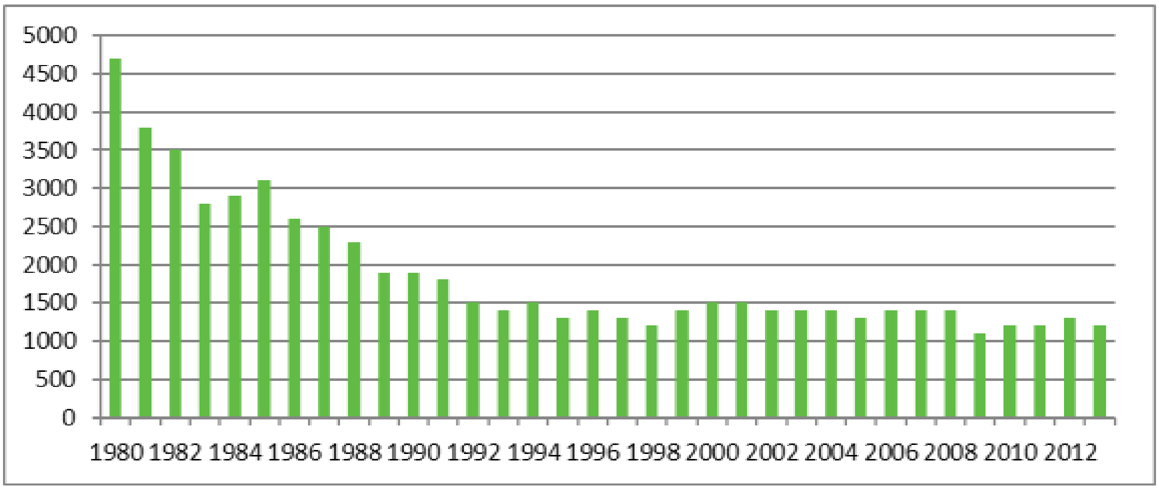

Figure C.28: Fires in USA warehouses by Year (NFPA, 2013)

The following figures compare industrial occupancies to other occupancies in terms of average number of fires per year. In each figure, the occupancies containing storage properties have been highlighted.

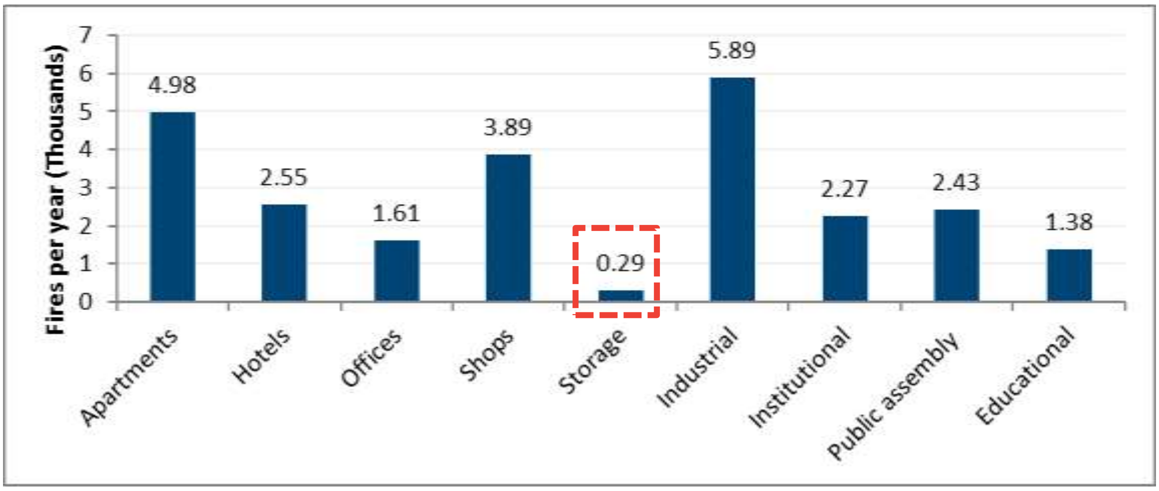

Figure C.29: Fires per year in Australia by Occupancy 1989-1993 (CSIRO, 2000)

In Australia, CSIRO data shows that storage buildings have the lowest frequency of fires of non-dwelling buildings (the CSIRO report does not include dwellings/Class 1 buildings).

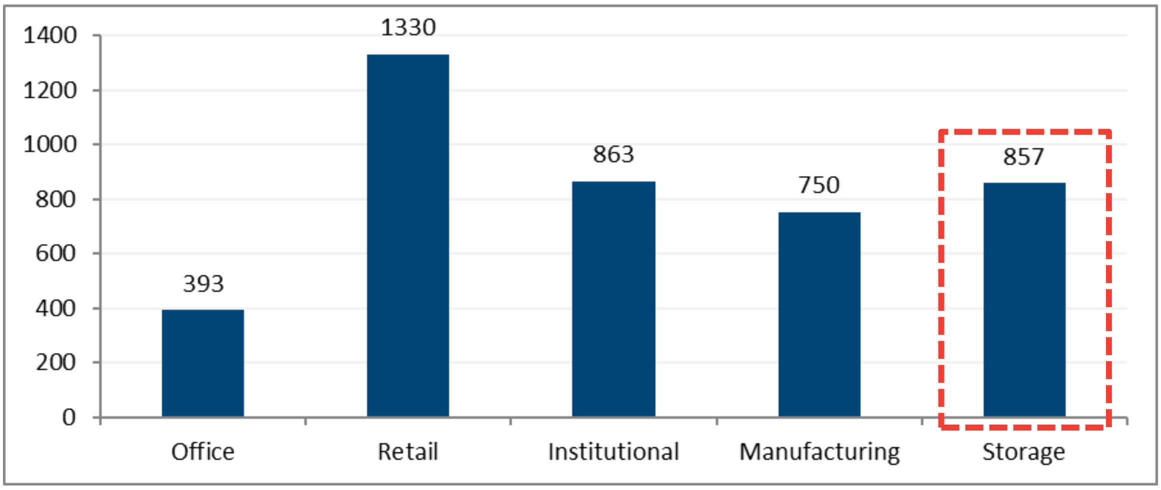

Figure C.30: Fires per year in Australia by Occupancy 1998-2004 (ARUP, 2008)

More recent data from AFAC shows more storage fires, in line with institutional and manufacturing properties. Possible reasons for this discrepancy include changes to definitions of occupancies or changes in fire safety practice in the five years between the studies, which may have focused improvements on the riskier occupancies. However, the greatest factor is likely to be the increasing sizes of warehouses, and the increased storage area within them.

Data worldwide indicates that warehouse fires are becoming more common and more extreme (Gottuk & Dinaburg, 2012). This is likely as a result of continued increases in storage quantity and efficiency increasing the fire loads and reducing the ability of occupants to detect or extinguish fire. Automatic storage and retrieval systems (ASRS) are especially dangerous in this way, with additional electronic ignition sources and aisles too small for humans to enter.

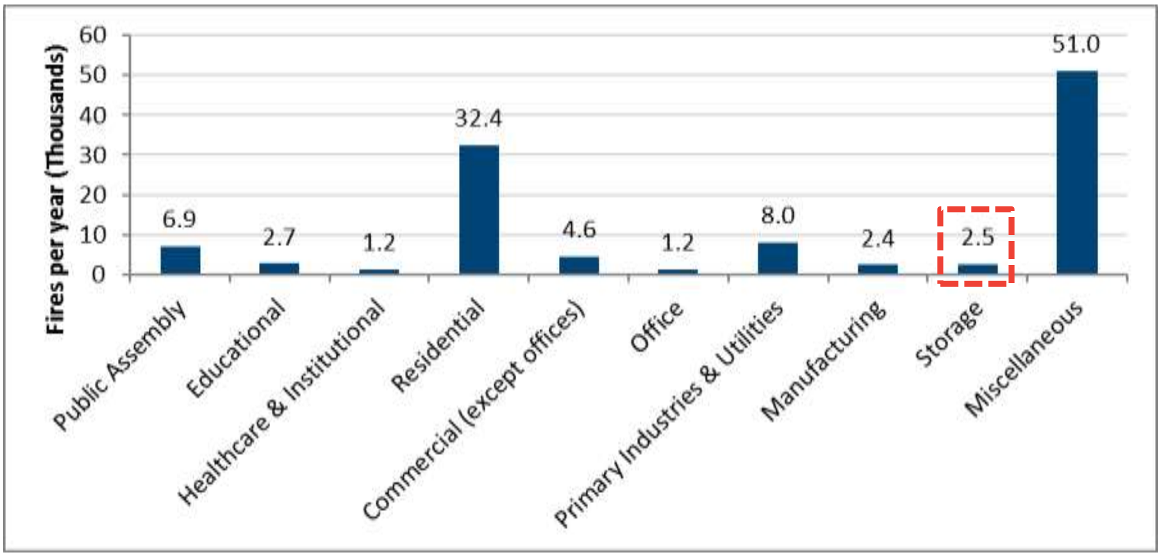

Figure C.31: Fires per year in New Zealand by Occupancy 2005/06-2009/10 (NZFS, 2010)

New Zealand data shows residential buildings as having the most frequent fires (the miscellaneous category includes many non-building locations). Storage buildings have significantly fewer fires per year, near the median for non-residential properties.

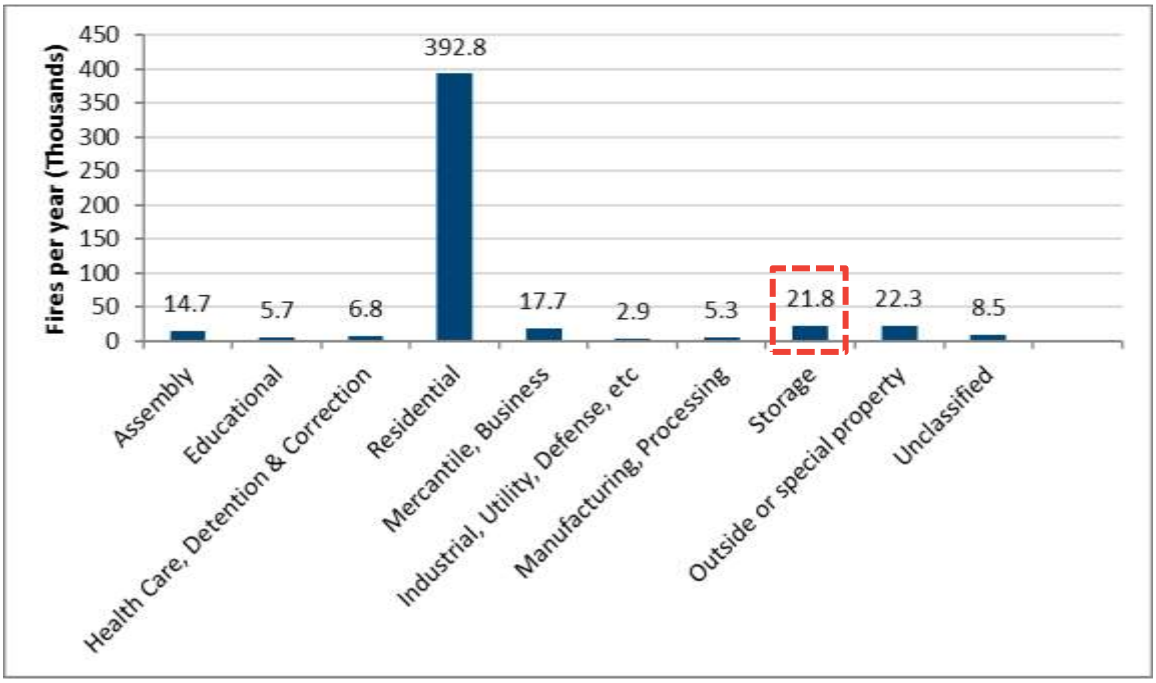

Figure C.32: Fires per Year in USA by Occupancy 2007-2011 (NFPA, 2013)

USA data too shows far more residential fires than any other occupancy, though here storage properties have more fires than most other categories.

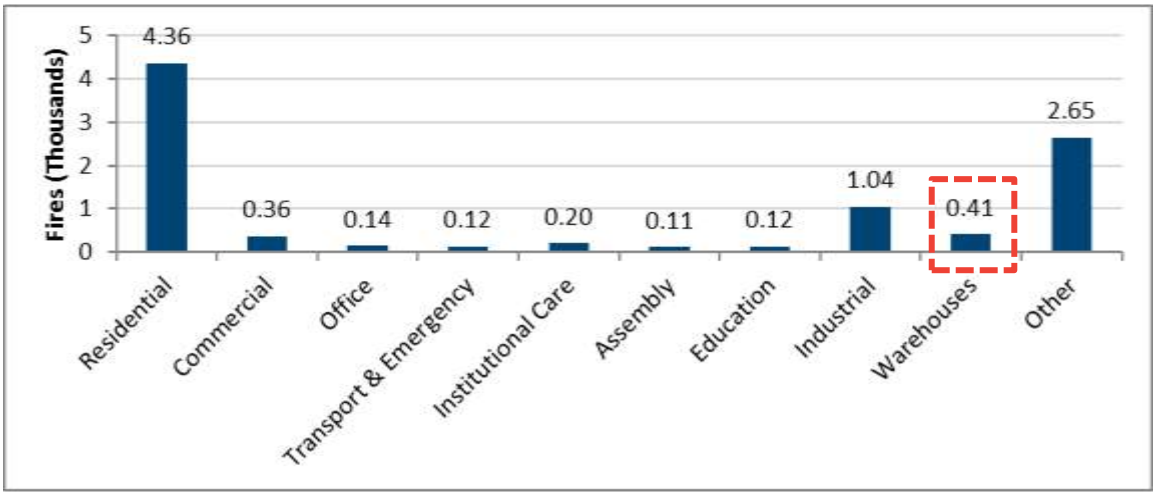

Figure C.33: Structure Fires in Finland by Occupancy 1996-99 (Tillander & Keski-Rahkonen, 2003)

Storage buildings are the occupancy with the third most frequent fires in Finland. Interestingly, this is not the case when the data is adjusted for floor area (Figure C.34), where warehouses have the greatest rate, indicating a lower floor area than most occupancies.

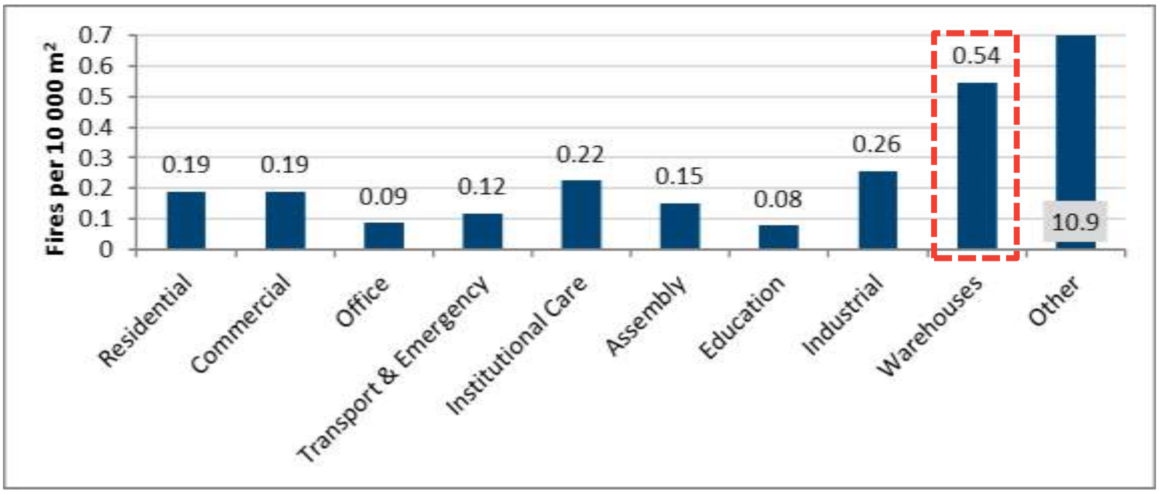

Figure C.34: Structure Fires per unit floor area in Finland by Occupancy 1996-99 (Tillander & Keski-Rahkonen, 2003)

Note that 'other' has a very low floor area, resulting in an ignition rate twenty times the next most frequent. This is largely irrelevant in this case because we are comparing storage buildings to other occupancies.

Thus, we see that the statistics worldwide indicate that a storage building rates quite high with respect to the risk of fire when compared to buildings of other occupancies, and only residential buildings consistently display greater frequency of fires. Therefore, effective and efficient fire safety systems and practices are of additional importance for reducing this risk in storage properties.

C.2.6 Risk to Life

A pair of very useful statistics in comparing fire risks is the rates of injuries and of fatalities, as they give a good overall impression of the life safety risk of the occupancy, separate from the frequency or intensity of fires. It is important to note, however, that it is still affected by the relative quantities of the different occupancies – there are far more residential buildings (for example) than storage buildings, naturally resulting in greater numbers of fires, injuries and fatalities in residential buildings.

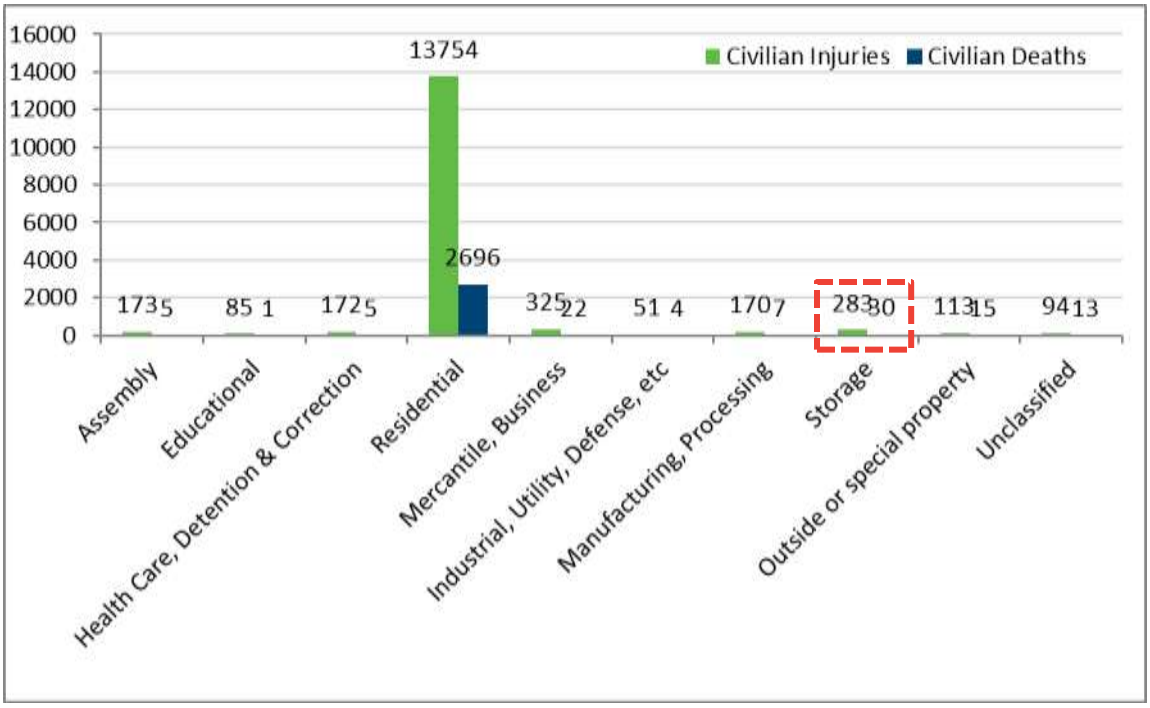

Figure C.35: Average Deaths and Injuries in USA Fires by Occupancy 2007-2011 (NFPA reports)

USA data indicates that the vast majority of fire deaths and injuries occur in residential buildings, a greater proportion even than the number of fires. Storage buildings, by contrast, have a low rate of injuries, though greater than those in most other occupancies. This is a lower number of injuries per fire than most other occupancies have, most likely due to the lower numbers of occupants in storage occupancies.

Additionally, sprinklers extinguish fire or prevent its spread in 94% of the cases where they are present and operate (AFAC, 2008)

Thus, we can conclude that storage occupancies have a low risk to life due to fire. This is most likely due to the low number of occupants present in storage buildings, and due to the proportion of fires set by arsonists, who tend to target valuable property and take steps to avoid injury.

C.2.7 Conclusion

While there is limited usable Australian fire statistics available, there are plenty of international sources of data (see Section C.2.2), and these overseas sources are relevant to the Australian built environment, so can be used with care to inform fire engineering and design in Australia. In storage occupancies in particular, this data leads to a number of observations:

- Fire loads in storage properties are extremely varied (see Table C.3), changing based on what product or material is being manufactured or processed, and also on the height of storage. Any fuel load for use in analysis will depend on the specific product and storage arrangements in question.
- The ignition sources that produce the most frequent fires in storage properties are arson, and mechanical and electrical failures (see Figure C.24). This is consistent with the overall lack of equipment or activity in storage occupancies, and indicates somewhat unique fire prevention needs.
- ***Statistics worldwide indicate that a storage building rates quite high with respect to the risk of fire when compared to buildings of other occupancies*** (see Section C.2.5)***, and only residential buildings consistently display greater frequency of fires. Therefore, effective and efficient fire safety systems and practices are of additional importance for reducing this risk in storage properties.***

In conclusion, storage occupancies have a low risk to life due to fire. This is most likely due to the low number of occupants present in storage buildings, and due to the proportion of fires set by arsonists, who tend to target valuable property and take steps to avoid injury.

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Appendix D. Relevant Extracts from BCA Report

mckenzie group

A Bureau Veritas Group Company

Regulatory Compliance Report

ESR Horsley Logistics Park

Lot 204, 327-335 Burley Road,

Horsley Park

Prepared for: ESR
Date: 12th May 2021
Revision: A

210351-04BCA

Table of Contents

Date	Rev No	No. of Pages	Issue or Description of Amendment	Assessed By	Approved By	Date Approved
12/05/2021	A	32	Report for Comment	Alex Ciecko		

210351-04BCA

1. Executive Summary

Development Overview

The proposed Stage 1 development consists of 6 industrial warehouses and associated offices at 327-335 Burley Rd, Horsley Park. This regulatory compliance report covers Lot 204 of the development

Compliance Summary

As Registered Certifiers we have reviewed the concept architectural design documents prepared by HLA Architects (refer appendix A) for compliance with the current building assessment provisions, i.e. the Building Code of Australia 2019 Amendment 1 (BCA).

This report has been prepared to assess the project against the Building Code of Australia to enable issuance of construction approvals. Further assessment of the design will be undertaken as the design develops to ensure compliance is achieved prior to approval being issued

Deviations from the Deemed-to-Satisfy Provisions

The assessment of the design documentation has revealed that the following areas deviate from the deemed-to-satisfy provisions of the BCA. These items are to be addressed to ensure compliance is achieved, either through design amendment to achieve compliance with the deemed-to-satisfy provisions, or through a performance solution demonstrating compliance with the Performance Requirements of the BCA:

No.	Description	DTS Clause	Performance Requirements
Fire Safety Items			
1	**Perimeter Vehicular Access** The following vehicular access paths will be required to be addressed as part of a performance-based fire engineered solution: ▪ The perimeter access measures up to 45m away from the building in lieu of 18m	C2.4	CP9
2	**Extended Travel Distances – to a point of choice and to an exit** Extended travel distances will be required to be addressed as part of the Fire Engineered Solution for the development in accordance with DP4 and EP2.2 of the BCA. Please refer to section 8 for the extended travel distances	D1.4	DP4, EP2.2
3	**Extended Travel Distances - Between Alternative Exits** Extended travel distances will be required to be addressed as part of the Fire Engineered Solution for the development in accordance with DP4 and EP2.2 of the BCA. Please refer to section 8 for the extended travel distances	D1.5	DP4, EP2.2

No.	Description	DTS Clause	Performance Requirements
4	**Fire Hydrants** Hydrants located below an awning to be considered external are to be address in a performance solution	E1.3	EP1.3
5	**Smoke Hazard Management** Smoke exhaust or smoke and heat vents required throughout the development. We note that the requirement for Smoke Exhaust may be rationalised through the Fire Engineered Solution for the development in accordance with Performance Requirement EP2.2 of the BCA.	E2.2	EP2.2
6	**Fire Hose Reels** If 50m Fire Hose Reel lengths are proposed to be utilised as part of the development, we note that this will be required to be included within the Fire Engineered Solution in accordance with Performance Requirement EP1.1 of the BCA.	E1.4	EP1.1
7	**Exit Signs** Direction signs will be installed at a greater distance from the Finish Floor Level (FFL) than 2.7m due to the ceiling height.	E4.6	EP4.2
Accessibility Items			
8	**Accessibility** Confirmation is to be sought if portions of the Warehouses are deemed inappropriate for disabled access to be provided as part of the design development phase of the project, and therefore a Clause D3.4 exemption maybe sought.	D3.4	
Miscellaneous Items			
9	**Weatherproofing of External Walls** As there are no deemed to satisfy provisions relating to the weatherproofing of external walls, a performance solution is to be provided by the façade engineer/registered architect demonstrating that the external walls comply with the requirements of Performance Requirement FP1.4.	-	FP1.4

The feasibility and any additional requirements that will apply as a result of the performance solution will need to be confirmed by the professional preparing the performance solution. Any performance solution will need to be prepared by a suitably qualified/accredited professional.

Any fire engineered solution relating to insert relevant CP9, EP1.3 & EP2.2 items will need to be approved after consultation with the NSW Fire Brigade as part of the Construction Certificate process.

Appendix E. Sprinkler Reliability and Effectiveness

E.1 Reliability and Effectiveness

Automatic sprinklers are highly effective elements of total system designs for fire protection in buildings. They save lives and property, producing large reductions in the number of deaths per thousand fires, in average direct property damage per fire, and especially in the likelihood of a fire with large loss of life or large property loss.

For all occupancy classifications, where sprinklers were present in the fire area and fire was large enough to activate sprinklers, the effectiveness of the sprinkler systems is significantly high (97% to 100%). Operational probabilities vary in US data but for majority of classifications remain above 90% (Aherns, 2017). The efficacy values show a similar trend. This excludes buildings under construction.

The US data showed that in the event of a fire the likelihood sprinklers operating and being effective is 88 % (i.e. fire being large enough to operate sprinklers and/or sprinklers being well maintained and effective).

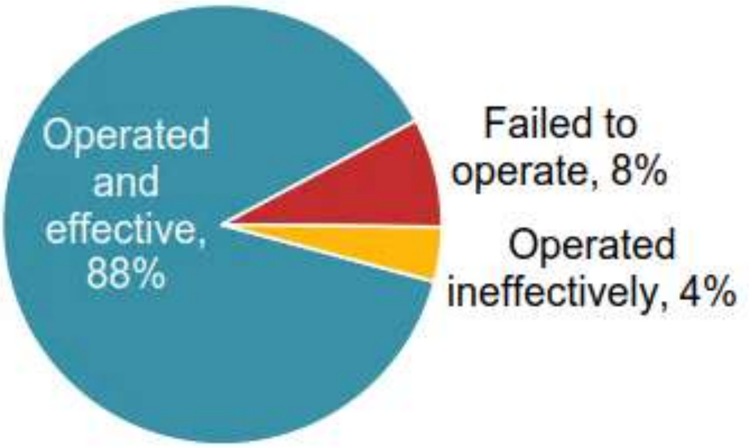

Figure E.1: Sprinkler operation and effectiveness (source: Ahrens, 2017)

Further research was performed specifically on U.S home fires, and it was identified that during 2010 to 2014 sprinklers operated in 94% of home fires; in which the fire was large enough to activate the sprinkler heads. It was further discovered that 96% of the fires were controlled effectively upon activation of sprinklers; and the sprinklers operated effectively in 91% of the fires (Ahrens,2017).

Whether with a performance design or with a prescriptive code, the reliability of fire protection systems and features must be considered. Reliability includes both operational reliability and performance reliability. The operational reliability is a measure of the probability that a system or component will operate as intended when needed. The performance reliability is a measure of the adequacy of the system once it has operated (Koffell, 2005). For a sprinkler system, operational reliability accounts for the “readiness” of the system components, while performance reliability addresses the “capability” of the system to perform satisfactorily under specific fire exposures.

Table E.1: Historical data on operational reliability (Koffell, 2005)

Reference	Reliability of Success	Comments
Marryat[1]	99.5	Inspection, testing, and maintenance exceeded normal expectations and higher pressures
Maybee[2]	99.4	Inspection, testing, and maintenance exceeded normal expectations.
Powers[3]	98.8	Office buildings only in New York City
Powers[4]	98.4	Other than office buildings in New York City
Finucane et al[5]	96.9 – 97.9	
Milne[6]	96.6/97.6/89.2	
NFPA[7]	88.2 – 98.2	Data provided for individual occupancies – total for all occupancies was 96.2%.
Linder[8]	96	
Richardson[9]	96	

Reference	Reliability of Success	Comments
Miller[10]	95.8	
Powers[11]	95.8	Low rise buildings in New York City
US Navy[12]	95.7	1964 – 1977
Smith[13]	95	UK data
Miller[14]	94.8	
Ahrens[15]	88	

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20. Miller, M. J., ibid.
21. Aherns,M. “US Experience with Sprinklers,” NFPA, July 2017, pp. 21. It should be noted that Ahrens’ data relates to operation and effectivenness and is not limited to reliability.

Most automatic sprinkler systems are designed to control a fire but not necessarily to completely extinguish the fire. The NFPA fire data supports the concept that sprinkler systems can control fires but do not necessarily result in complete extinguishment. Table E.2 indicates the percentage of fires where any type of sprinklers are present and that are reported as being extinguished by a sprinkler system.

Table E.2: Sprinkler reliability and efficacy – US data (Ahrens, 2017)

Property	Percent where sprinklers operated (A)	Percent effective of those operated (B)	Percent where equipment operated effectively (AxB)
Residential homes and apartments	94%	96%	91%
Office / commercial	91%	96%	87%
Educational	87%	96%	84%
Heath care including Nursing home, hospital, clinic, doctor’s office, or development disability facility	85%	97%	82%
Large Retail / Department Store	90%	98%	88%
Warehouse and cold storage	86%	96%	82%

Property	Percent where sprinklers operated (A)	Percent effective of those operated (B)	Percent where equipment operated effectively (AxB)
Hotel / Motel	90%	98%	89%
All public assembly	90%	94%	85%

The sprinkler effectiveness in reducing loss of life has been documented in the paper titled “US Experience with Sprinklers” (Ahrens, 2017). The following statistical data is summarised based on data collected during the period of 2010-2014.

Table E.3: Estimated reduction in 2010-2014 civilian deaths per thousand fires

Property Use	Civilian Deaths per Thousand Fires		
	Without Sprinklers	With Sprinklers	Percentage Reduction
Public Assembly	0.7	0.0	100%
Residential	7.5	1.1	84%
Manufacturing	1.6	1.0	21%
Warehouse excluding cold storage	2.7	0.6	74%
All structures	6.3	0.8	86%

With reference to Table E.3, in all structures, in average civilian fatalities have be reduced by up to 86% for all structure fires during the five year period due to the presence of sprinklers.

Table E.4: Number of sprinklers operating in 2010-2014 Structure Fires (Ahrens,2017)

Number of Sprinklers Operating	Percentage of structure fires where that many sprinklers operated
1	79%
1 or 2	91%
1 to 3	94%
1 to 4	96%
1 to 5	97%
1 to 10	99%

Table E.4 indicates the percentage of structure fires where that many sprinklers operated. The table shows that generally in structure fires, more than 90% of structure fires have resulted in an activation of more than 1 sprinkler head. Therefore, it can be said that in a sprinkler protected building, typically more than 1 sprinkler head activates in an event of a fire, which reassures the reliability of automatic sprinkler systems.

E.2 Sprinkler Performance in Other Occupancy Classifications

Carparks

All carparks accommodating more than 40 vehicles are required to be provided with sprinkler systems in Australia. Studies show that sprinklers are significantly effective in carparks

Based on UK fire data the sprinkler effectiveness in carparks assumed to be as high as 99%. Between 1994 and 2005 there were 3095 report fires in car parks in the UK. Of these, only 162 fires occurred where a fixed fire suppression system was present. Automatic fire sprinklers extinguished or contained 100 of these fires. In only 1% of cases, fire sprinklers operated but did not extinguish or contain the fire. It is assumed that the remainder were too small to actuate the sprinklers and either simply burned out or was extinguished quickly by persons using fire extinguishers etc. (UK Fire Statistics, 2010).

The most modern car designs, with increased flammability, are adequately protected by the latest sprinkler system designs because rapid rises in temperature cause earlier operation of the system which prevents faster fire spread, thus causing much less smoke and heat. Although sensitive to rapid heat increases caused by fire, inadvertent operation of a sprinkler system is virtually unknown due to “built in” integrity (Eurofeu Technical Report, 2009).

E.3 Failures that may be Attributed to the Sprinkler Systems

Several of the causes of failure are attributable to the human factor. This leads to a discussion about which causes of failure that really should be attributed to the sprinkler system. Based on the study conducted by Ahrens (2017), it was shown that there are several reasons that contributed to sprinkler failures.

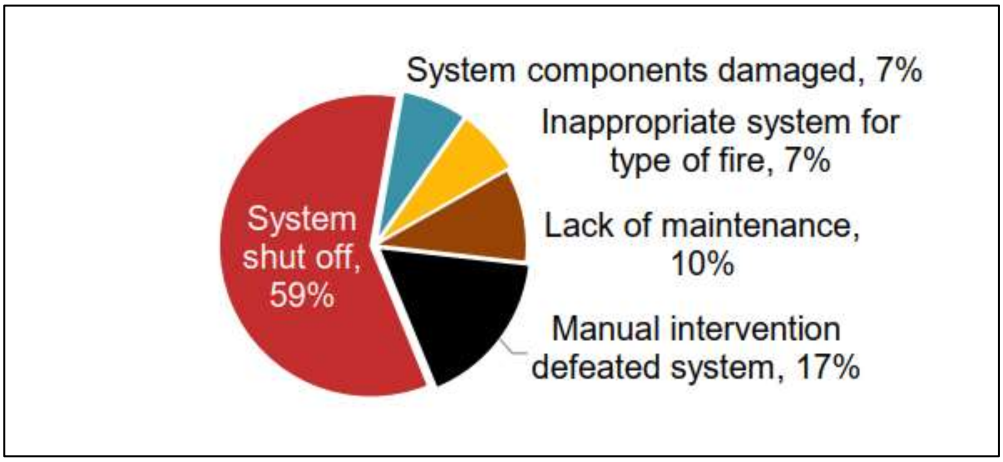


Figure E.2: Reasons for sprinkler failures: 2010-2014 (Ahrens, 2017)

As shown in Figure E.2, 59% of the time the systems were shut off leading to failure in sprinkler activation. Manual intervention was the secondary contribution to sprinkler systems failing to operate, followed by lack of maintenance, systems components damaged and inappropriate system for type of fire.

Further studies were also conducted to determine the reasons for sprinkler effectiveness. Based on the study by Ahrens (2017), over the 5 year period between 2010 and 2014, 51% (half) of the fires in which sprinklers were ineffective were due to the water not reaching the fire. It was also determined that 30% of the incidents were due to the limited amount of water discharged. In 7%, system components were damaged.

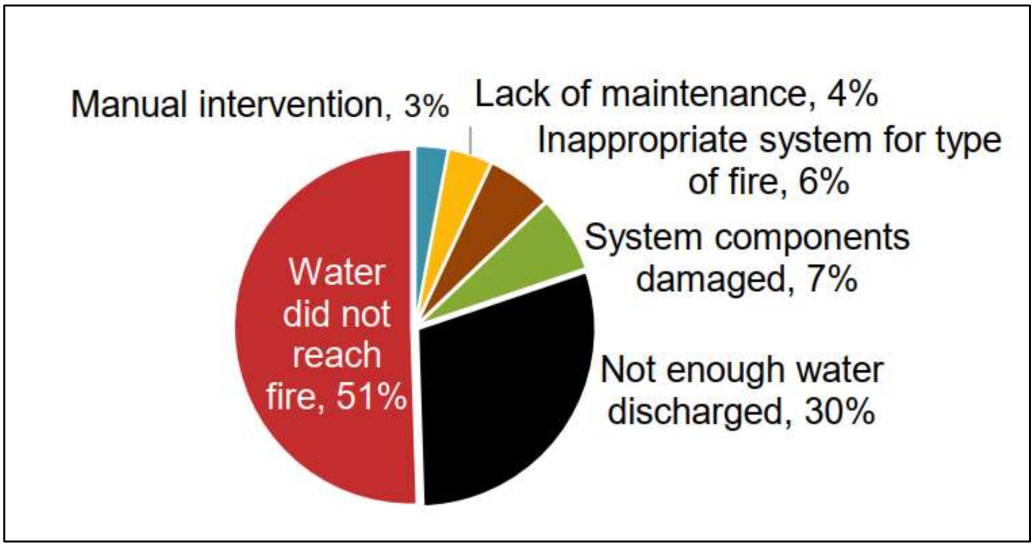


Figure E.3: Reasons for sprinkler ineffectiveness: 2010-2014 (Ahrens, 2017)

Furthermore, based on research data extracted from “Efficiency and Effectiveness of Sprinkler Systems in the United Kingdom: An Analysis from Fire Services Data” by the National Fire Sprinkler Network (NFSN) (May, 2017), it was determined that there were “additional” reasons for the sprinkler system to not operate.

Table 5: "Other" Reasons for System not Operating		
	Number	**%**
Insufficient fire or heat	115	79.3
Extinguished before activation	13	9.0
No fire, just smoke/not enough smoke	7	4.8
Fire contained to machine	5	3.4
Operating failure	3	2.1
Human error	1	0.7
Flash fire in cotton dust	1	0.7
Total	**145**	**100.0**
Source: Optimal Economics		

Figure E.4: "Other" Reasons for System not Operating

As extracted from **Table 5** of the "Efficiency and Effectiveness of Sprinkler Systems in the United Kingdom: An Analysis from Fire Services Data" by the National Fire Sprinkler Network (NFSN) (May, 2017), Figure E.4 shows that's the majority of cases where sprinkler systems do not operate is due to insufficient fire or heat (i.e. 79.3% of the time). Human error and flash fire in cotton dust are also responsible for the sprinkler system not operating but was considered highly unlikely (i.e. 0.7% of the time).

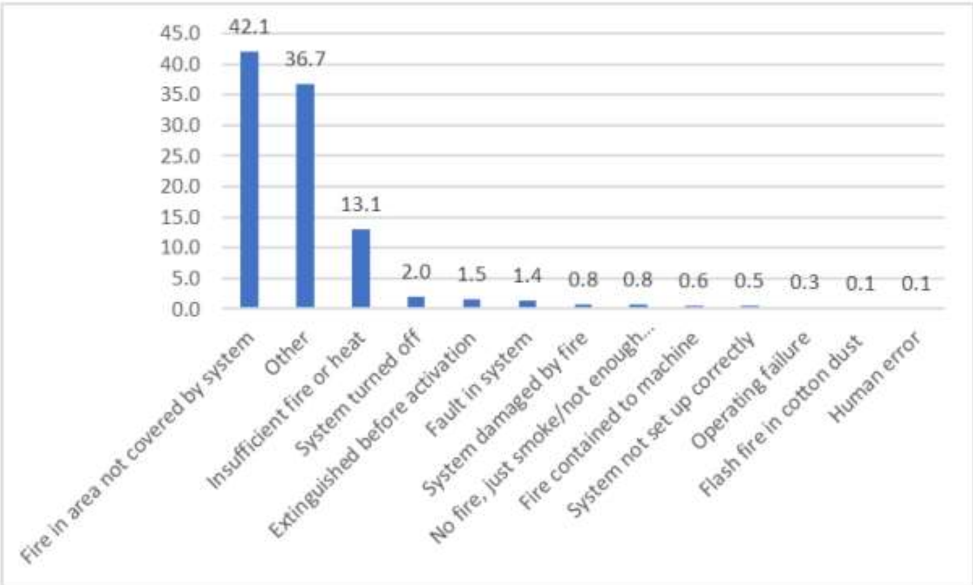


Figure E.5: Distribution of Reasons for Sprinkler not Operating. %

As shown in Figure E.5, the distribution of reasons for sprinkler not operating extracted from the research paper by the National Fire Sprinkler Network (NFSN) (May, 2017) shows that the main reason for sprinklers not operating is due to insufficient coverage by the sprinkler system within the area of fire origin (AFO).

In summary, it can be said that automatic sprinkler systems are highly reliable and the main reasons the systems do not operate are generally due the following:

- Lack of fire/heat within the area of fire origin; and
- Insufficient coverage by the system within the area of fire origin

E.4 Impact of Sprinkler Systems on Fire Temperatures and Heat Release Rates

With the presence of sprinklers, the likelihood of a fire growing to the extent where it will spread beyond the object of fire origin is considered unlikely. Sprinkler protection is expected to provide a reliable and effective means of maintaining tenable conditions for occupants and fire-fighters, structural adequacy, and limiting fire spread within the subject building as well as to adjacent building(s). Effective sprinkler activation and operation is also likely to reduce the generation of smoke and maintain low compartment temperatures thus mitigating smoke spread between adjacent compartments.

Experimental evidence and numerical studies have demonstrated that sprinklers are very effective in controlling and suppressing fires. Sprinkler systems are designed to contain a fire. Madrzykowski & Vettori (1992) have conducted single (small) room experiments to study the effect of sprinklers on the heat release rate (Nystedt,2011).

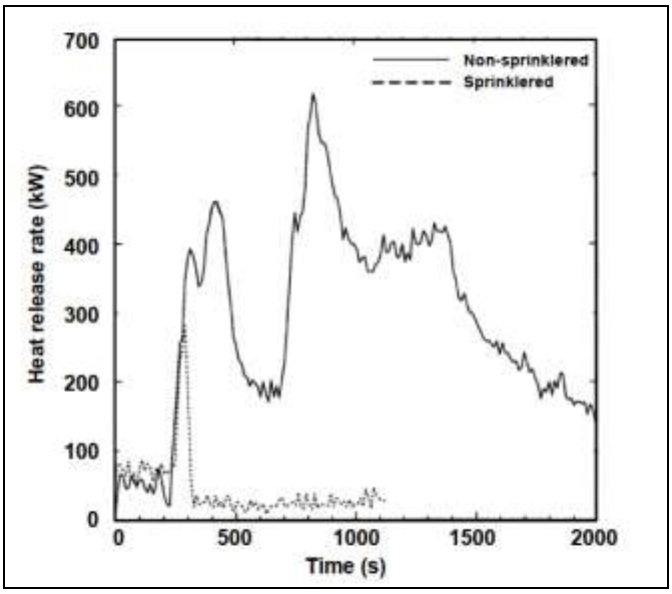


Figure E.6: Illustration of sprinkler effect on the fire development for a sofa fuel package (adopted from Madrzykowski & Vettori, 1992)

As shown in Figure E.6, the peak heat release rate in a sprinkler protected room is no more than 300 kW at the time of sprinkler activation, but the heat release rate peaks at approximately 600kW in a non-sprinkler protected room.

Further to the experiment conducted by Madrzykowski & Vettori, the Building Research Establishment in the UK (BRE,2002) has conducted a project that characterised fires for design purposes. The sprinkler tests were carried with a maximum of four sprinklers operating with a total rate of 270 litres per minute and with a pressure of 0.6 bar at the sprinkler heads. As defined by the British Standard BS5406 (BSI,2009) the sprinkler system was designed according to Ordinary Hazard Class III. Utilising the output from the BRE design fires, the Swedish Fire Sprinkler Association (Sprinklerframjandet) has financed a study to evaluate the difference between sprinklered and non-sprinklered fires (Lindsten, 2009).

Table E.5: The effect of sprinklers on the heat release rate (Lindsten, 2009)

Test	Immediate Effect	Secondary Effect
Open Plan Office	Reduced HRR	HRR reduced by 50% after 1 min
Luggage	Increased HRR by 25% - 50%	HRR reduced by 50% after 2-3 min
Reception	Reduced HRR	Extinguished after 2 min
Carpets	Reduced HRR	Extinguished after 1 min
Sports clothing	Increased HRR by 25%	Extinguished after 2 min
Pallets	HRR kept constant	None
Adventure Play Area	Reduced HRR	Extinguished after 2 min
Boxes	HRR kept constant	None
Soft Toys	Reduced HRR	Extinguished after 2 min

As shown in Table E.5, Lindsten (2009) concludes that the fire is extinguished by the sprinkler system in 50% of the fire tests. Three tests results showed a reduced in heat release rate and the remaining two tests showed that the heat release rate were maintained.

Multi/ large room experiments were also carried out to determine the effectiveness of sprinklers. The experiments were carried out by Schonberg (2000) in a room with a floor area of $14m^2$ and a ceiling height of 2.6m. Further experiments were conducted by Crocker et al. (2010) to study the impact of sprinklers sprays on the fire induced doorway flow. Based on the 34 experiments conducted, it was concluded that a spray sprinkler reduced the mass flow at the doorway while maintaining two stratified layers away from the sprinkler spray. In this instance, temperature measurements from both an unsprinklered and sprinklered cases are shown in Figure E.7.

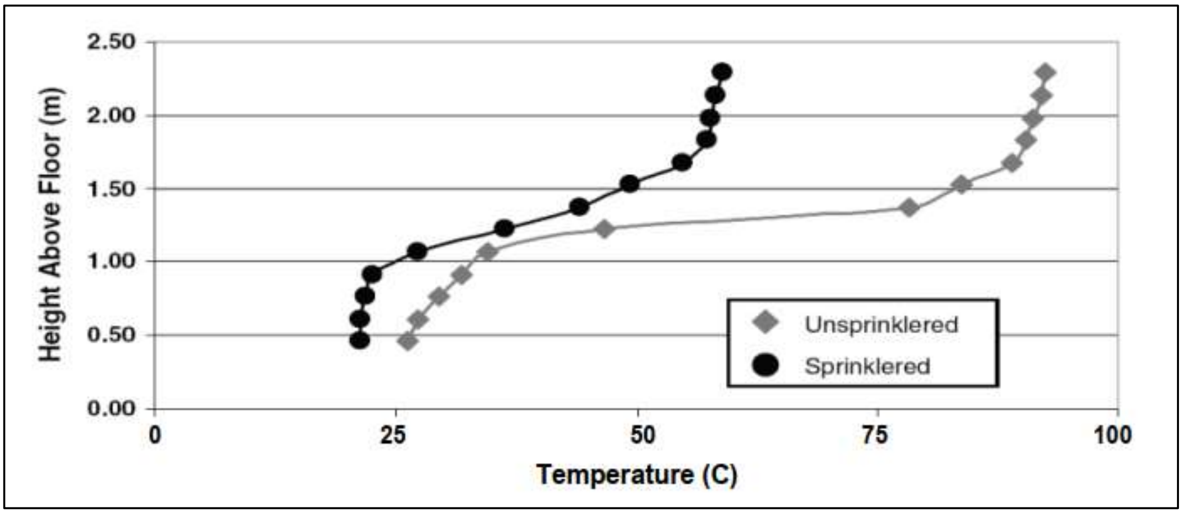


Figure E.7: Temperature measurements inside the compartment (Crocker et al. (2010))

Automatic sprinklers are capable of suppressing or controlling fires such that the temperature rise of fire product gases and radiant heat is significantly reduced. It is assumed that the hot layer gases remain at the same temperature, as they were when the sprinklers activate which is approximately 75-100°C. It is evident that the effect of sprinklers on a fire is to wet down potential fuel sources, control or suppress the burning process and to cool the resultant smoke layer. It has been cited that the resultant smoke temperatures in a sprinkler-controlled fire are reduced to 100°C -120°C (Milke, 2001; Madrzykowski, 2008) within 60 seconds of sprinkler activation. (Refer to Figure E.8 to Figure E.9).

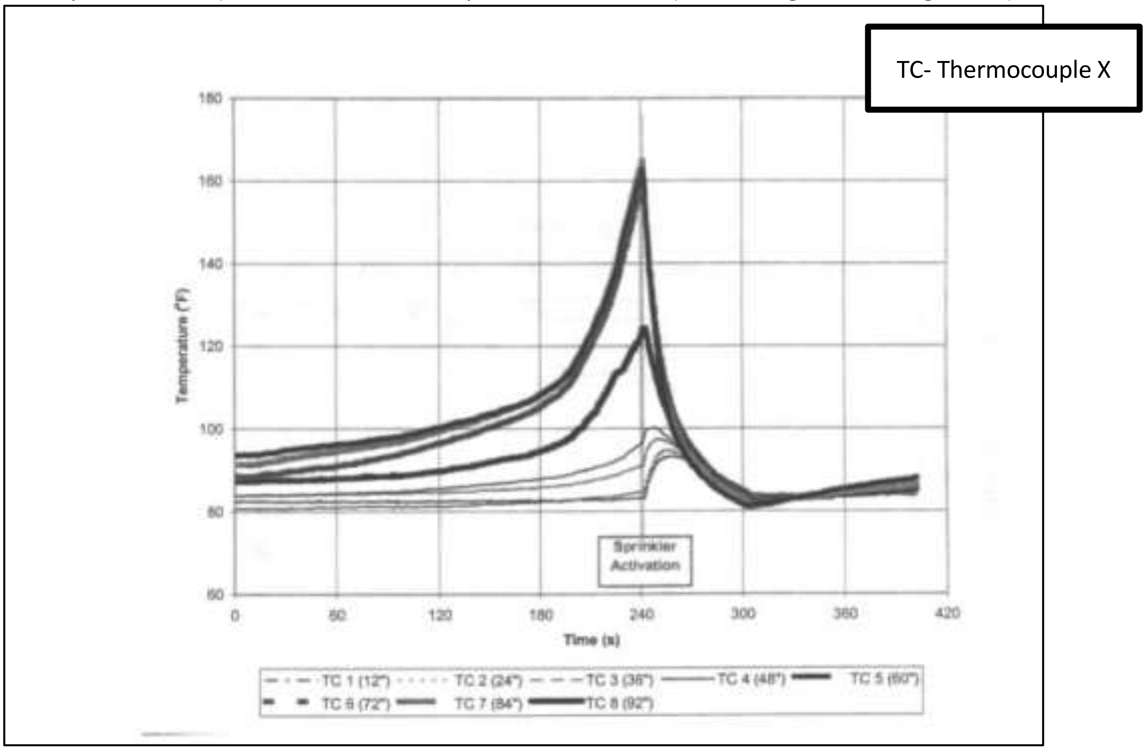


Figure E.8: Sprinkler controlled room temperatures (Milke, 2001)

With the presence of the sprinkler systems the risk of distress to building elements, barriers and the like is minimal. When a sprinkler system is activated within an enclosure a room fire the heat release rate of the burning fuel is reduced or controlled to a relatively small level. Similarly, the smoke and hot gas temperatures inside the room of fire origin are reduced or maintained due to the cooling effect of water spray.

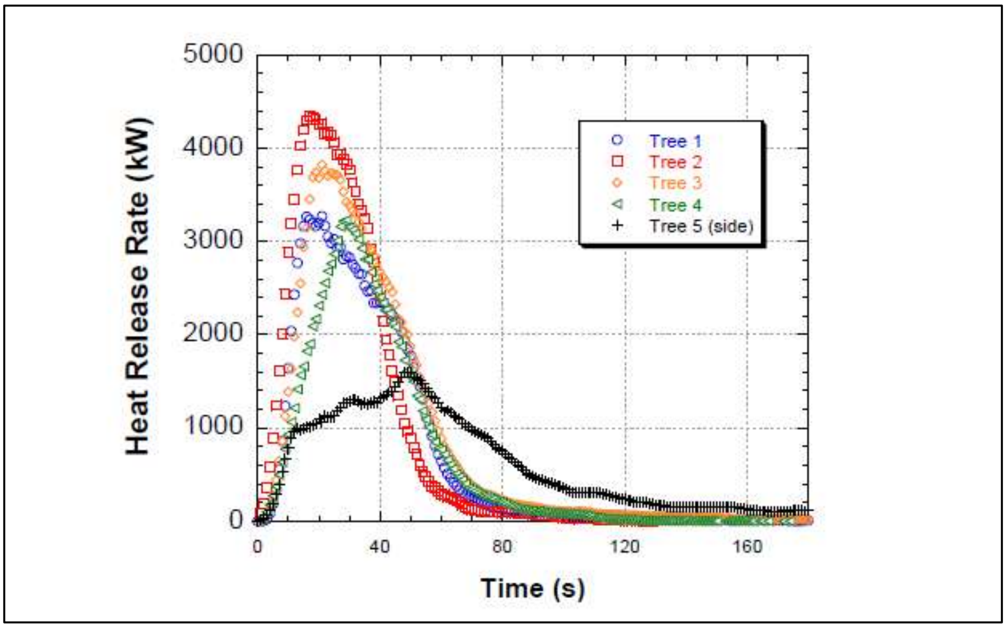
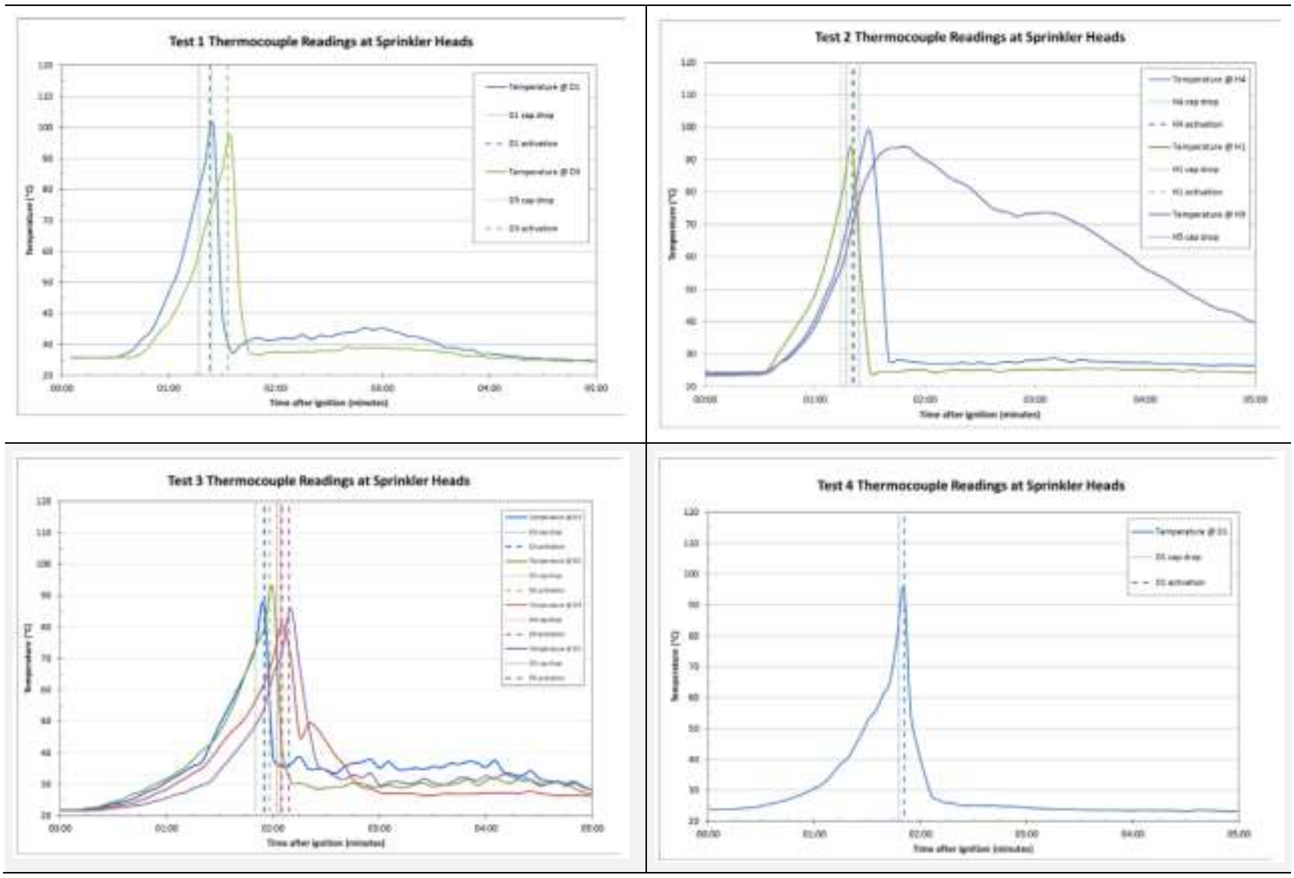
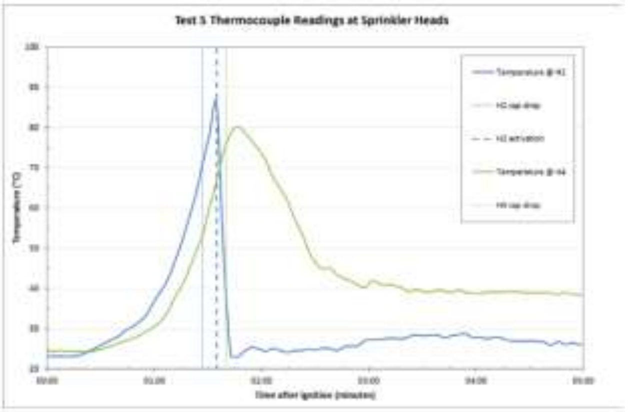
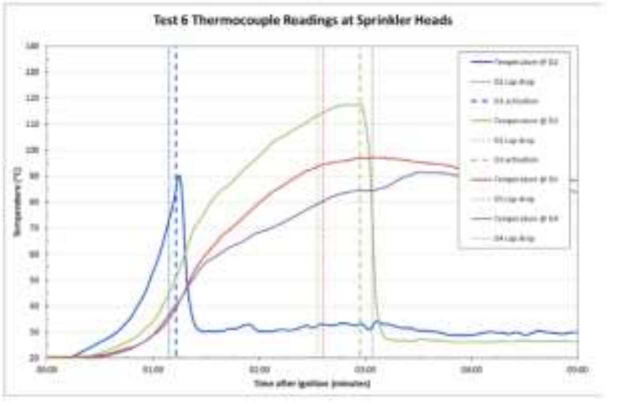


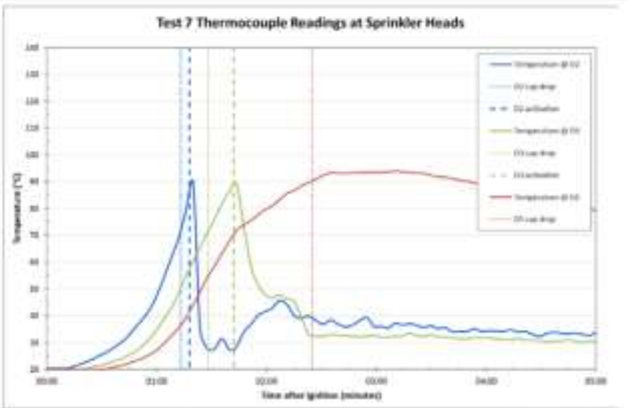
Figure E.9: Reduction in heat release rates with sprinkler activation (Madrzykowski, 2008)

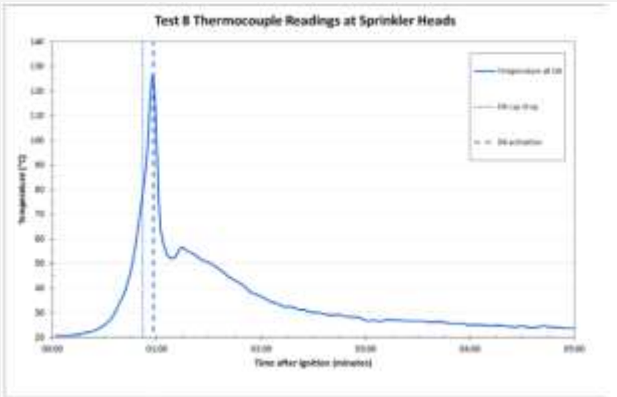
Based on the "Fire Research Report – Residential Sprinkler Research" (FRNSW, 2017), fourteen (14) tests were conducted to determine the reliability and effectiveness of automatic sprinkler systems within residential buildings of more than 25m in height. Out of the fourteen (14) tests, thirteen (13) tests were provided with sprinklers and the results have revealed a consistency in sprinkler activation times and temperature at the time of activation (Refer to Figure E.10). In relation to the effects of sprinklers on heat and atmospheric tenability, sprinklers had a significant effect on both aspects within the structure.

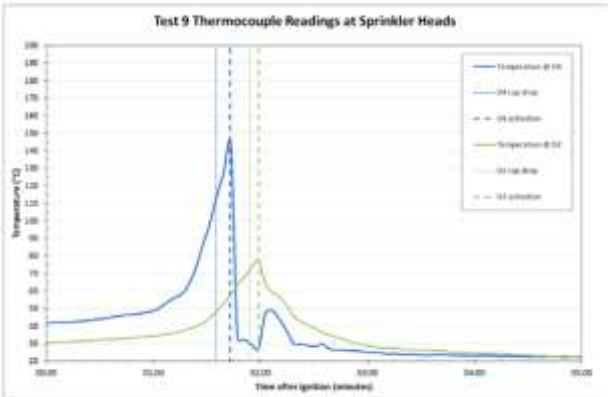


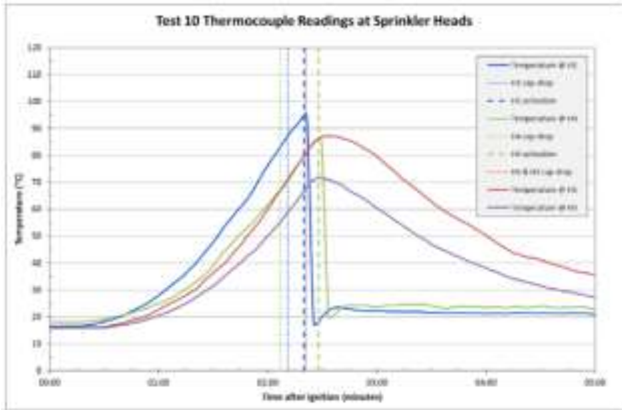

Test 5 Thermocouple Readings at Sprinkler Heads
Time after ignition (minutes)

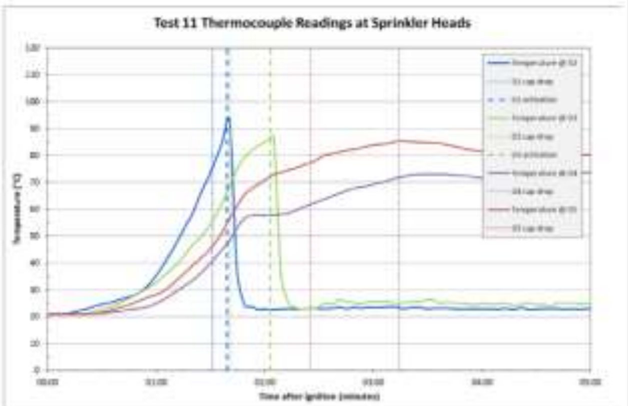

Test 6 Thermocouple Readings at Sprinkler Heads
Time after ignition (minutes)

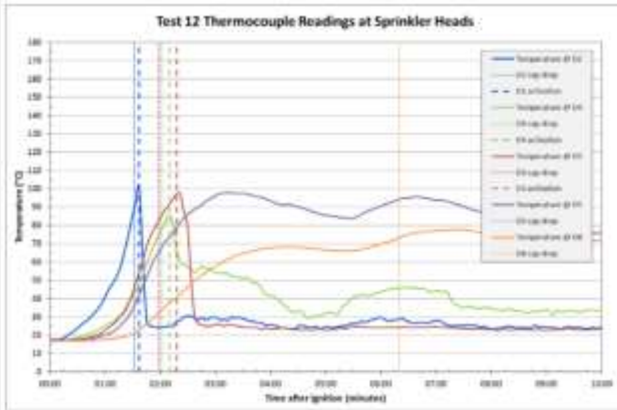

Test 7 Thermocouple Readings at Sprinkler Heads
Time after ignition (minutes)


Test 8 Thermocouple Readings at Sprinkler Heads
Time after ignition (minutes)


Test 9 Thermocouple Readings at Sprinkler Heads
Time after ignition (minutes)


Test 10 Thermocouple Readings at Sprinkler Heads
Time after ignition (minutes)


Test 11 Thermocouple Readings at Sprinkler Heads
Time after ignition (minutes)


Test 12 Thermocouple Readings at Sprinkler Heads
Time after ignition (minutes)

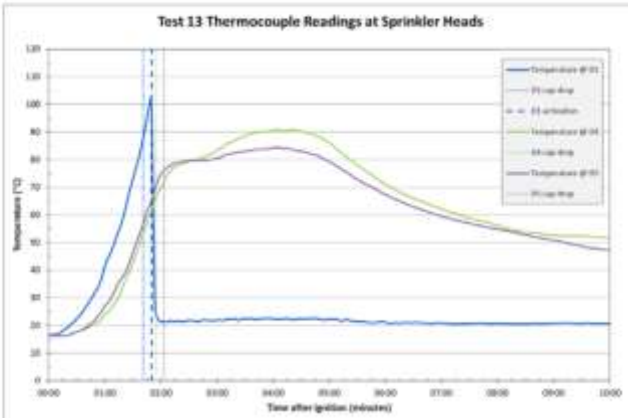


Figure E.10: Reduction in temperature with sprinkler activation (FRNSW, 2017)

It has come to a conclusion that sprinklers can maintain a lower compartment temperature as compared to a non-sprinkler protected compartment. Sprinkler activations had the effect of cooling conditions within the unit and preventing fire growth. Based on the abovementioned research data, it is clear that the activation of automatic fire sprinklers significantly improves the tenability of occupants in the event of a fire.

E.5 Conclusion

In conclusion, global data demonstrates that sprinkler systems are highly reliable especially in buildings where regular inspections and maintenance is conducted. Operational probabilities vary in US data but for majority of classifications remain above 90% (Aherns, 2017). The efficacy values show a similar trend.

Furthermore, once sprinklers activate the temperatures are expected to be reduced to approximately between 120°C and 100°C within 60 seconds of the activation. The Heat Release Rate profiles also follow a similar downward trend upon activation of sprinklers.

Appendix F. Fire Dynamics Simulator (FDS)

F.1 General

F.1.1 Fire Dynamics Simulator

FDS is a powerful fire simulator which was developed at the National Institute of Standards and Technology (NIST). The NIST field model FDS is a Computational Fluid Dynamics (CFD) model of fire-driven fluid flow. The FDS software is appropriate for low-speed, thermally-driven flow with the emphasis on smoke and heat transport from fires (K B McGratten et-al 2002).

The FDS model to be used is a deterministic 'fire model' which is used to predict the spread of heat and smoke in an enclosure or multiple enclosures. Visual presentations of the FDS simulation modelling results has been provided using the 'smokeview' program (K B McGratten et-al 2002).

The NIST FDS is a CFD model, or sometimes referred as a field model. Field models rely less on empirical correlations and are based on solving conservation equations for mass, momentum and energy. Fluid dynamics involves mathematical equations that describe the physical behaviour of fluids (gases and liquids) and are in the general form of three-dimensional, time-dependent, non-linear partial differential equations known as the ‘Navier-Stokes’ equations.

- **Current FDS release version:** FDS 6.7.1
- **Current Smokeview release version**: SMV 6.7.4

F.1.2 Applications of the Fire Dynamics Simulator Software

The FDS software models have been used to establish (but not limited to) the following applications:

- Low speed transport of heat and combustion products from a fire; and
- Radiative and convective heat transfer between gas and solid surfaces/materials; and
- Pyrolysis; and
- Flame spread and fire growth; and
- Activation of devices such as a smoke detector(s), heat detector(s), sprinkler head(s), etc; and
- Sprinkler sprays and suppression by water.

F.2 Basic CFD Input Information

F.2.1 CFD Grid Size Justification

An approach recommended by Bounagui et al. (Bounagui, A; Kashef, A; Benichou, N, 2003) was utilised in quantitatively determining the suitability of the grid resolution adopted. An important parameter that may be referred to in determining the suitability of a grid resolution is the characteristic fire diameter, D* which is defined as shown in Equation 1. The grid size ratio Gr (Equation 2) is then calculated to look at the number of cells in the region. Higher ratios signify better numerical model predictions. FDS program (NIST) suggests the grid size ratio should be greater than 4.

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

Eq.1

Grid Size Ratio = $D^*/\Delta\delta$

Eq.2

where:

D^* :	characteristic fire diameter
Q :	total heat release rate, kW;
ρ_∞ :	density at ambient temperature, kg/m^3 = 1.2;
Cp :	specific heat of gas, kJ/kg.K = 1.0;
T_∞ :	ambient temperature, K = 298;
g :	acceleration of gravity, m/s^2 = 9.81;
G_r :	grid size ratio

$\Delta\delta$: grid size, m.

The flow is buoyancy driven Δz (grid resolution in z direction) is very influential in FDS fire models.

A fine grid resolution shall be adopted for areas near the fire source. In areas remote from the fire larger grid resolutions shall be adopted. Since the flow is buoyancy driven, Δz (grid resolution in z direction) is very influential.

Grid size resolution, which is a function of the physical fire size, magnitude and grid interval, shall be used to identify the level of accuracy of the models constructed.

As long as burner sizes are compatible with the grid resolutions (i.e. larger burners with large grid sizes) model accuracy is known to be maintained even with large grid resolutions. The burner sizes shall be varied based on different the scenarios to be modelled.

F.2.2 CFD Fire Surface Area Justification

The area of the fire surface used for the fire needs to be justified such that it represents a credible fire scenario. The Fire Dynamics Simulator Technical Reference Guide Volume 3: Validation (i.e. page 57). To calculate the most appropriate area of the fire surface the Fire Froude Number $\dot{Q}^*$ has to be calculated. The fire Froude Number is a non-dimensional quantity for plume correlations and flame height estimates. It is essentially the ratio of the fuel gas exit velocity and the buoyancy-induced plume velocity.

It should be noted that jet fires are characterized by large Froude numbers. Typical accidental fires have a Froude number near unity (i.e. 1). Typical accidental fires are the common fire scenario used in ASET/RSET analysis. Furthermore, An Introduction to Fire Dynamics (Drysdale page 130) states that turbulent jet fires occur when $Q^* > 5$ and pool fires occur when $Q^* < 1$. The Fire Froude Number $\dot{Q}^*$ is shown below:

$$\dot{Q}^* = \frac{\dot{Q}}{\rho_\infty c_p T_\infty \sqrt{gD}D^2}$$

Eq.1

where:

D: characteristic fire diameter

Q : total heat release rate, kW;

ρ_∞ : density at ambient temperature, kg/m^3 = 1.2;

Cp : specific heat of gas, kJ/kg.K = 1.0;

T_∞ : ambient temperature, K = 294;

g : acceleration of gravity, m/s^2 = 9.81.

Table F.1: Calculated Froude number

Fire Scenario	Total HRR (kW)	Fire Dimension	Calculated Fire Diameter	Calculated Q*
HP01C_8.6WA	8,600	2.0m x 2.0m	2.257	1.037
HP02S_16.5WA	16,500	2.0m x 2.0m	2.257	1.989
HP03S_8.6WD	8,600	2.0m x 2.0m	2.257	1.037
HP04S_8.7WS	8,700	2.0m x 2.0m	2.257	1.049

Based on the calculations in Table F.1, it was concluded that the diameter size adopted for the above fire scenarios was appropriate to simulate an accidental fire such that 1< (Q^*) <5, which shall be the basis for the fire scenarios.

F.2.3 Visibility C Factor

In FDS analysis where visibility is used as tenability criteria the C factor if the signage (if there is any) is a key parameter. In the context of the current project a C factor of 8 has been adopted based on the presence of illuminating signage.

F.2.4 Boundary Conditions

The boundary conditions for the smoke modelling were as follows:

- Air temperature: 20°C
- Outside walls are adiabatic.
- The compartment floor and roof modelled as concrete, using the standard materials database provided with FDS.
- The model is surrounded by free, neutral pressure boundaries.

F.2.5 Adopted Fuel

The adopted Fuel input is as per the following:

- SOOT_YIELD = 0.075 (refer to justification below)
- NU_O2 = 3.7
- NU_CO2 = 3.4
- NU_H2O = 3.1
- MW_FUEL = 87.
- EPUMO2 = 11020.

F.2.6 Adopted Soot Yield

For warehouse facilities, it is difficult to determine the exact nature of fuel loads given the size of variances in use. However, the soot yield within the warehouse is determined based on the likely distribution and characteristics of such combustible materials that would be expected within a typical warehouse facility.

Soot yield is the smoke represented by carbon particles distributed through the gas layers. Typically, fire modelling inputs are in the form of a yield (mass of carbon per mass of fuel pyrolysed in g/g or kg/kg).

Soot yield values for well-ventilated free burning fires involving "sooty" fuels are in the range 0.008 –0.18 g/g with lesser values appropriate for clean burning fuels and wood products. As part of the FDS model to be conducted the soot concentrations have been determined based on referenced data and/or a weighted average of soot yield. The average soot yield is based on a function of the soot yield characteristics for a range of likely materials expected within the building. Soot yield values for the expected commodities are as follows:

Table F.2: Soot Yields appropriate to a variety of materials

Fuel	Soot Yield (kg/kg)
Polyurethane (rigid) Foam	0.125
Plastics (Nylon)	0.075
Corrugated Paper Boxes	0.061
Silica	0.020
Polyester	0.091
Hydrocarbon	0.059
Butadiene	0.125
Wood	0.015
PVC	0.172
Synthetic material (PMMA)	0.022
Synthetic material (PE)	0.007

From the above, a soot yield value has been nominated based on the following points:

- Taking into consideration the large volume and height of the warehouse facility, it can be assumed that in the event of a fire the amount of soot being deposited on the ceiling structure will be less in comparison to a smaller enclosure such as an office tenancy where more soot would be expected to be contained within the smoke layer; and
- Due to the open nature of the warehouse, a fire is expected to be well ventilated involving a composition of materials with a range of soot yields extracted from text references (as listed above); and
- The vast majority of material soot yields detailed above range from 0.007kg/kg to 0.172kg/kg; and
- An average of the above equates to a soot yield of 0.070kg/kg.

Based on the above, it is proposed to round up and conservatively adopt a soot yield value of 0.075kg/kg for fire modelling purposes.

F.3 CFD Input Parameters

F.3.1 Summary of CFD Input Parameters

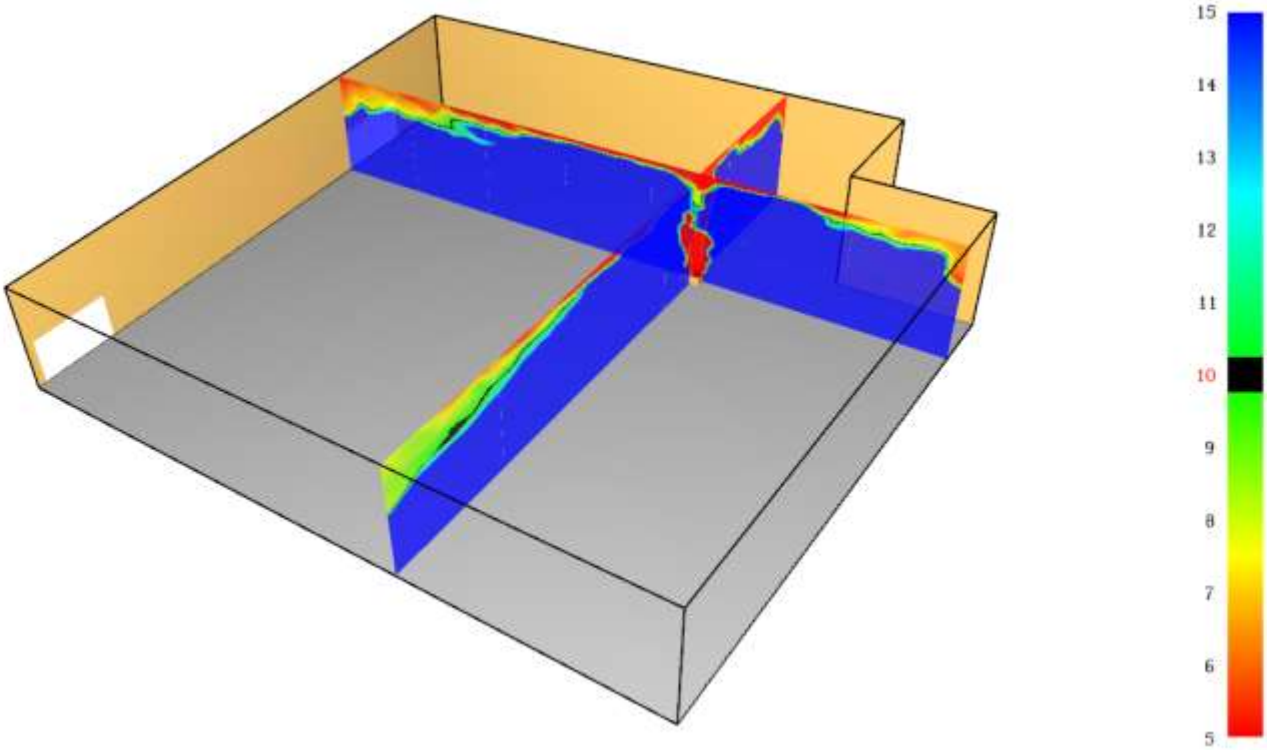
General / Domain Parameters	
Number of meshes	Approximately Twenty (20)
Type of mesh (e.g. Cartesian)	Cartesian Grid (FDS Default)

General / Domain Parameters				
Mesh Size	1.0m x 1.0m x 0.5m			
Material Properties	The floor to be modelled as concrete, the roof to be modelled as steel and the partition walls and ceiling to be modelled as plasterboard. These have been calculated using the standard materials database provided within FDS.			
Boundary Conditions	Outside walls are adiabatic surface to determine modelled boundary profiles. The model is surrounded by free, neutral pressure boundaries			
Steady-State or Transient	Steady state environment has been adopted.			
Simulation Time	2700 seconds. Extended simulation time to account for conditions for fire brigade life safety			
Fire Parameters				
Reaction Properties	Reaction properties based on the composition of materials such as plastics, wood, etc. NU_O2 = 3.7 NU_CO2 = 3.4 NU_H2O = 3.1 MW_FUEL = 87. EPUMO2 = 11020.			
Soot Yield (value and means of including in model)	0.075kg/kg has been adopted for the fire scenarios to represent warehouse commodities.			
Visibility Factor (or other parameters used to obtain Visibility output)	The visibility factor of 8 has been adopted representative of a illuminated exit signage at visibility distance of 10m.			
Heat Release Rate Per Unit Area (HRRPUA)				
	HP01C_8.6WA	8,600	2.0m x 2.0m	2,150 kW/m²
	HP02S_16.5WA	16,500	2.5m x 2.5m	2,640 kW/m²
	HP03C_8.6WD	8,600	2.0m x 2.0m	2,150 kW/m²
	HP04S_8.7WS	8,700	2.0m x 2.0m	2,175 kW/m²
Means of achieving fire growth rate (e.g. ramp, multiple fire objects, etc.)				
	HP01C_8.6WA	Ultra-Fast t^2		
	HP02S_16.5WA	Ultra-Fast t^2		
	HP03C_8.6WD	Ultra-Fast t^2		
	HP04S_8.7WS	Custom		
Fire locations (including height above floor)				
	HP01C_8.6WA	Warehouse A	13.7m	
	HP02S_16.5WA	Warehouse A	13.7m	
	HP03C_8.6WD	Warehouse D	13.7m	
	HP04S_8.7WS	Warehouse D	13.7m	
Mechanical smoke exhaust	N/A			
Mechanical supply air	N/A			
Jet fans	N/A			
Natural vents	N/A			
Natural make-up air	Natural fresh air intake provided via roller shutter door openings. For the purpose of the model, 50% of the roller shutters will be opened to allow natural ventilation.			
Assumed building leakage	Leakage based on number of openings through external walls.			

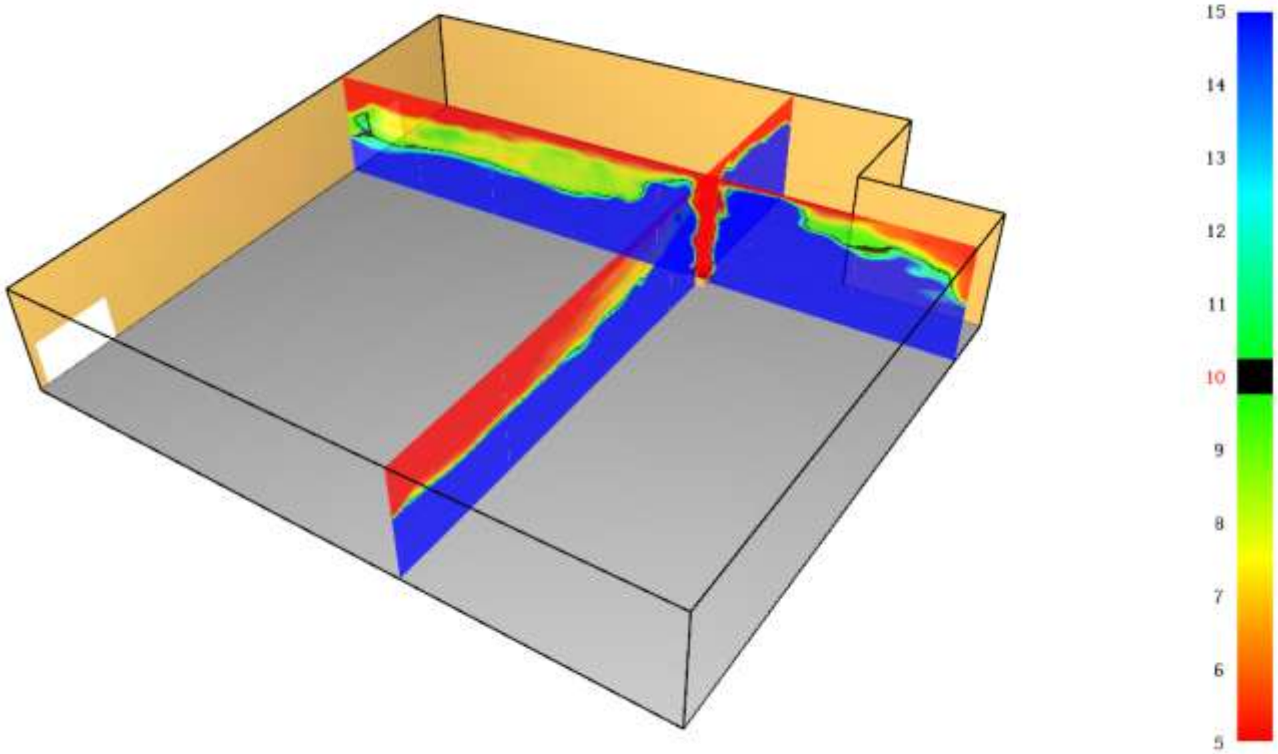
General / Domain Parameters		
Sprinklers (RTI, spacing, location, distance to fire, temperature rating, etc.)		
	Activation Temperature	100°C
	Response Time Index	$50m^{0.5}s^{0.5}$
	Sprinkler Head Height	13.7m
	Sprinkler Head Spacing	3.1m x 3.1m
	Radial Distance to Fire	2.2m

F.4 CFD Outcomes

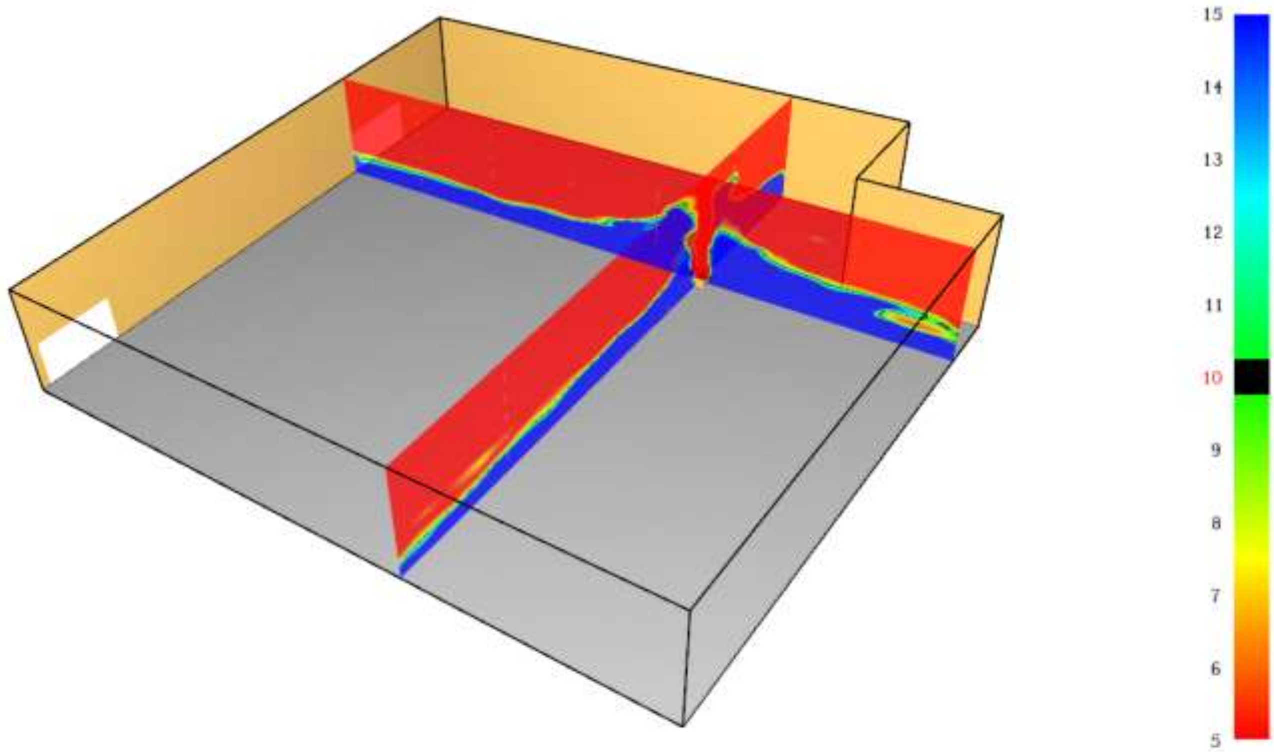
F.4.1 HP01C_8.6WA



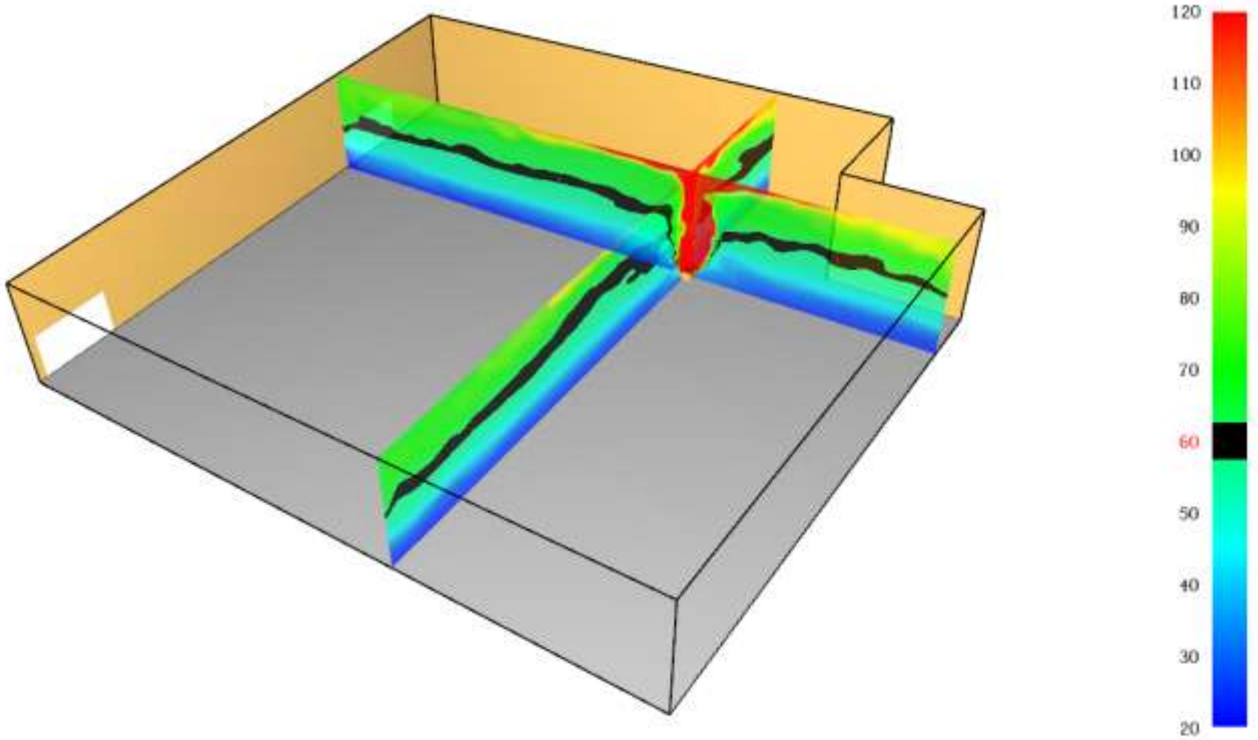
Visibility Snapshot at 220 seconds (RSET)



Visibility snapshot at 330 seconds (1.5x RSET)

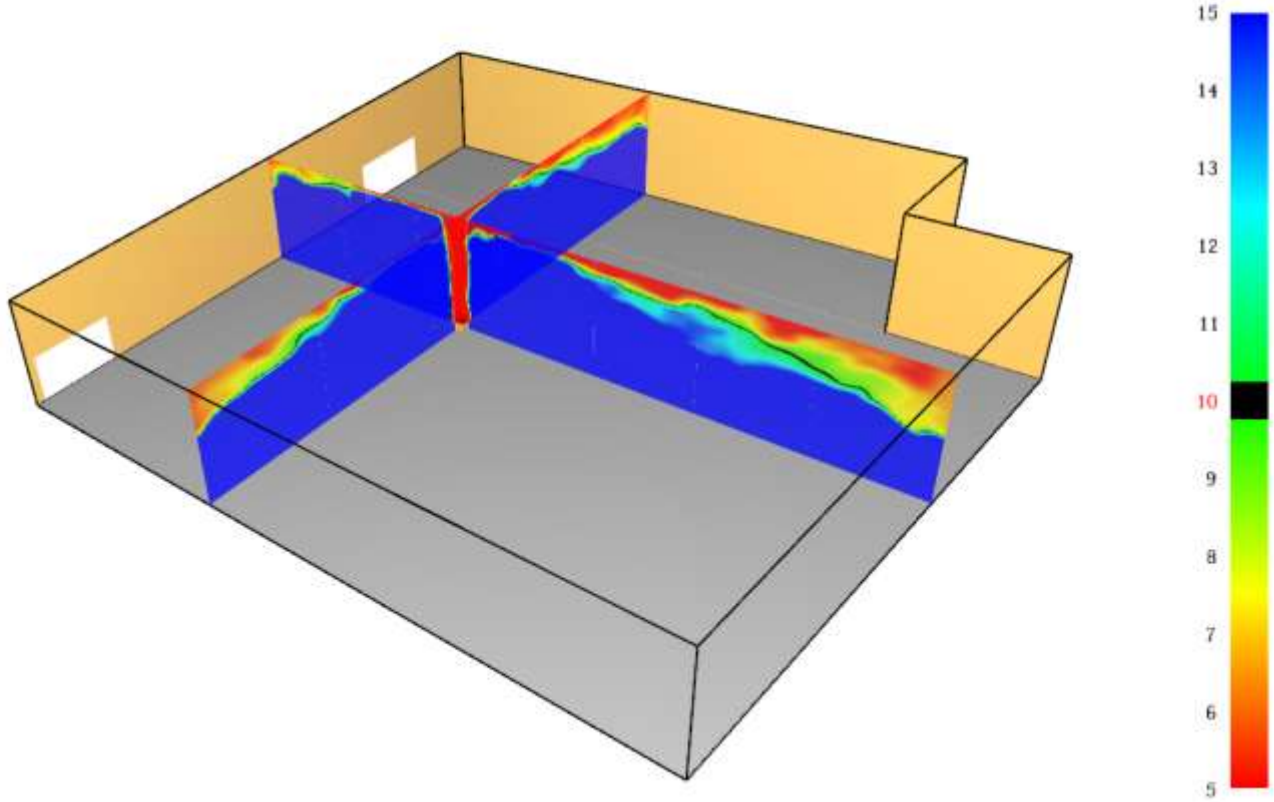


Visibility snapshot at 800 seconds (ASET)

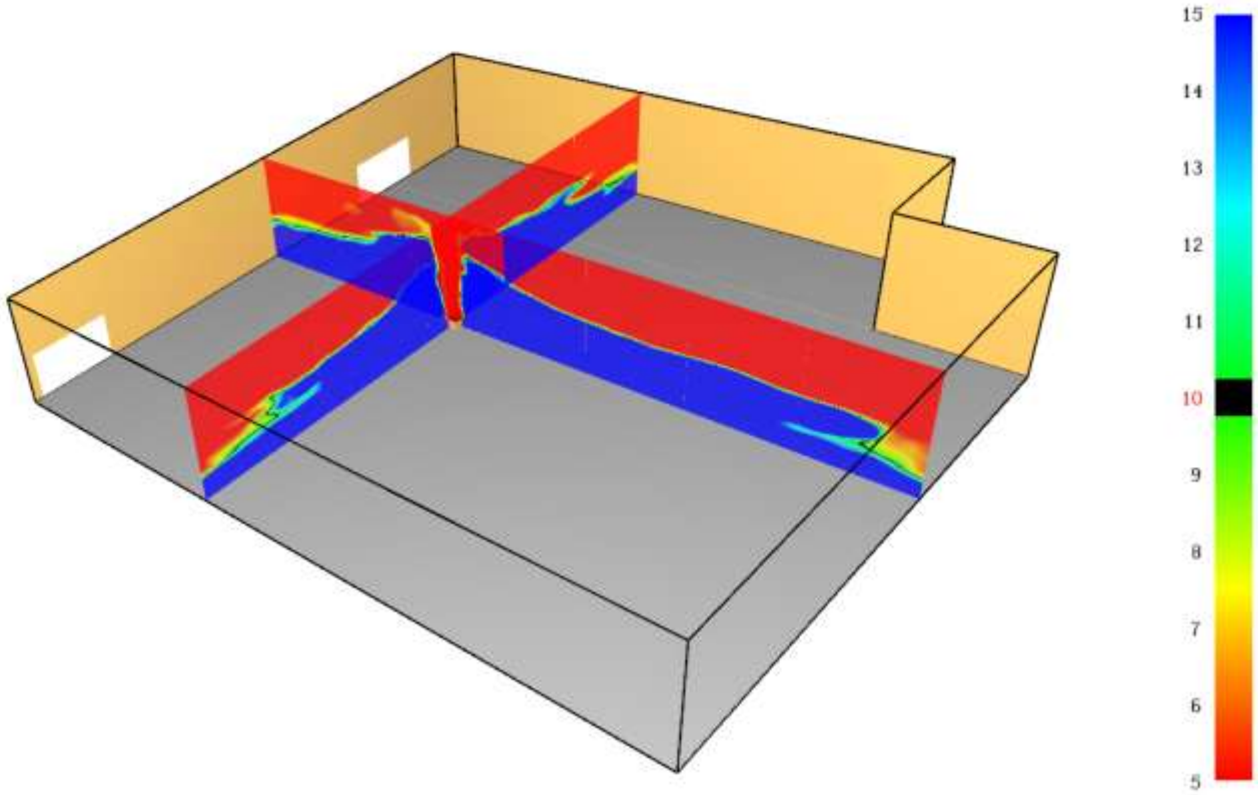


Temperature snapshot at 2700 seconds

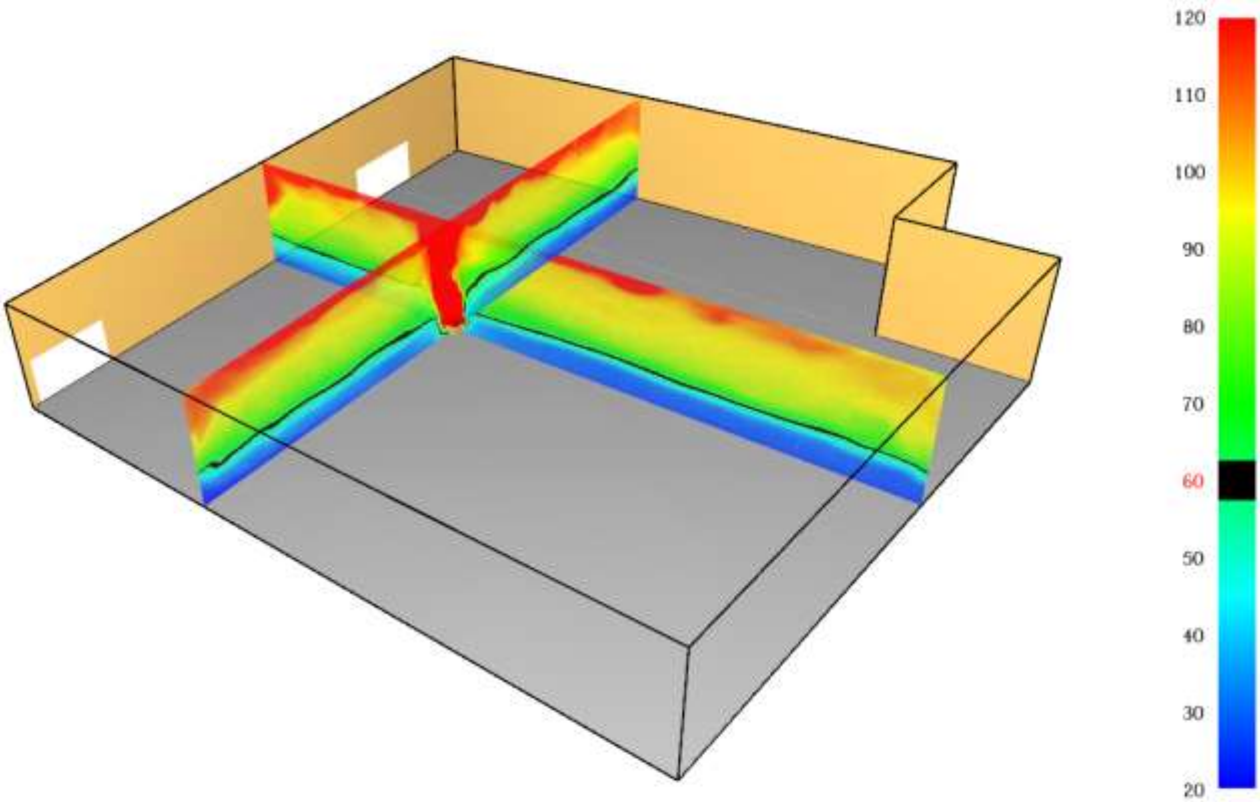
F.4.2 HP02S_16.5WA



Visibility snapshot at 235 seconds (RSET)

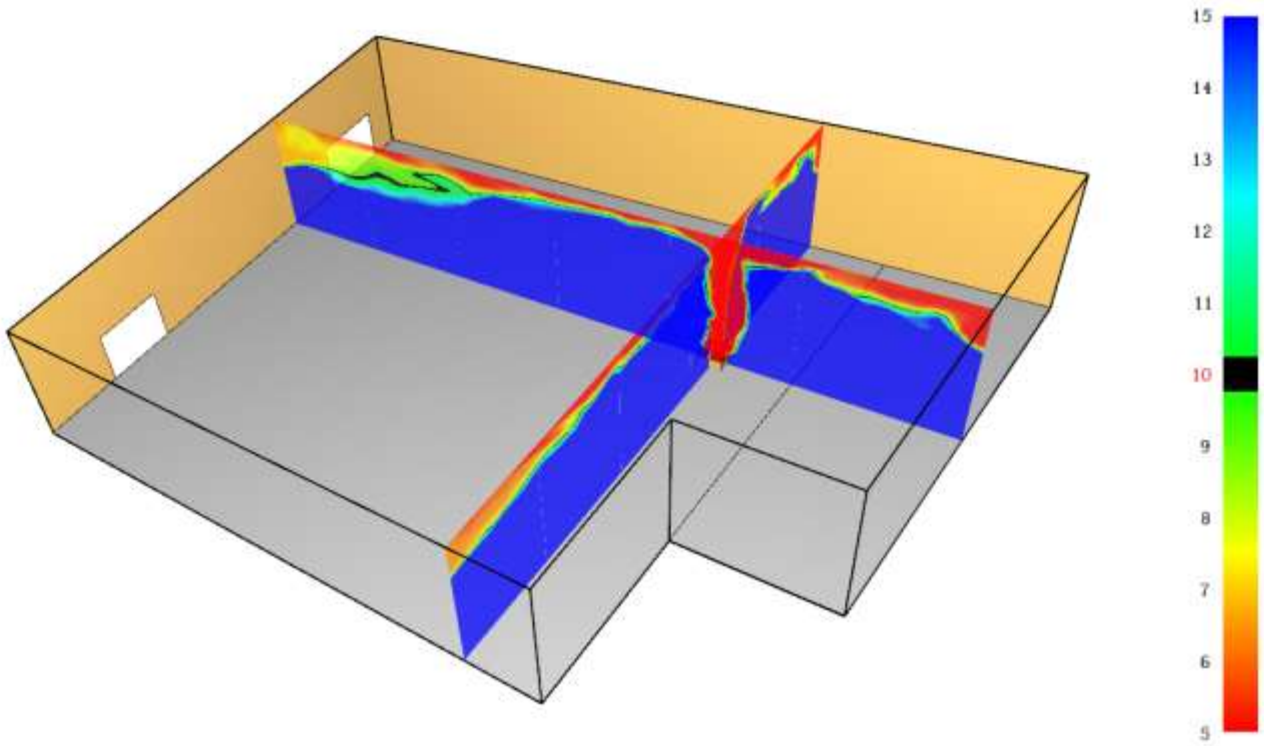


Visibility snapshot at 450 seconds (ASET)

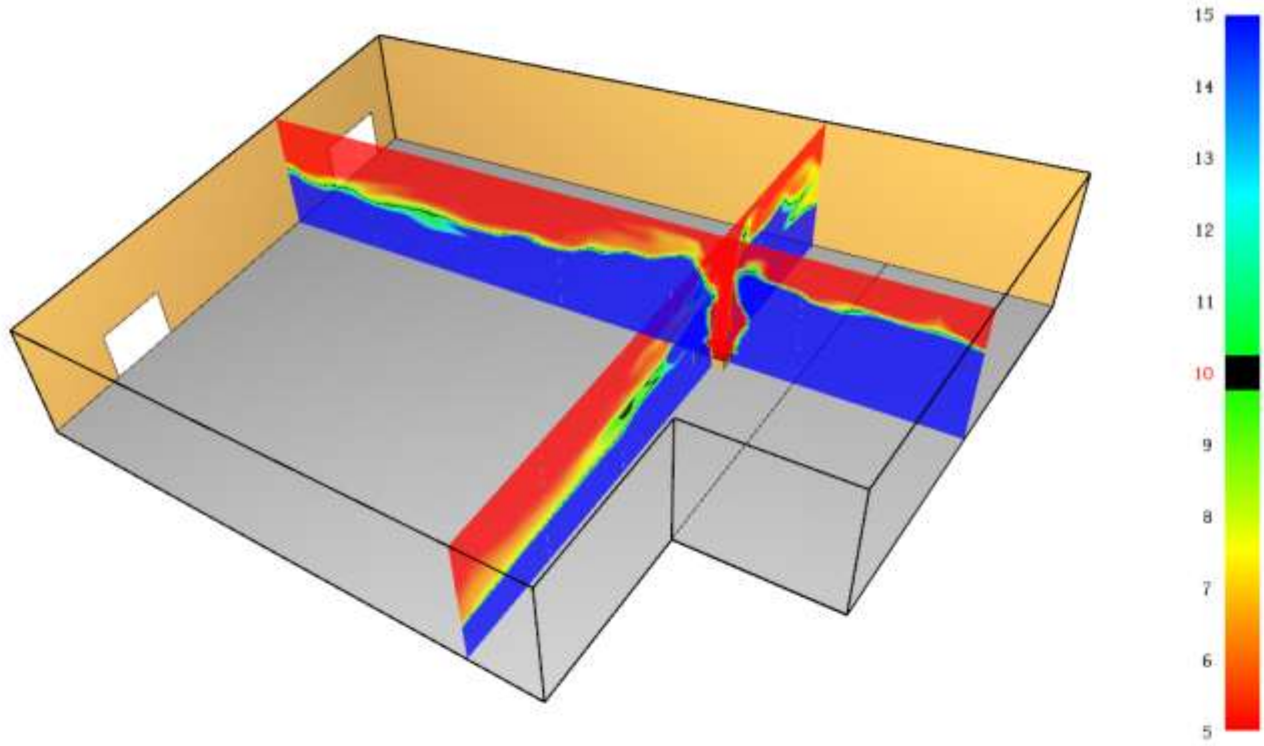


Temperature snapshot at 2700 seconds

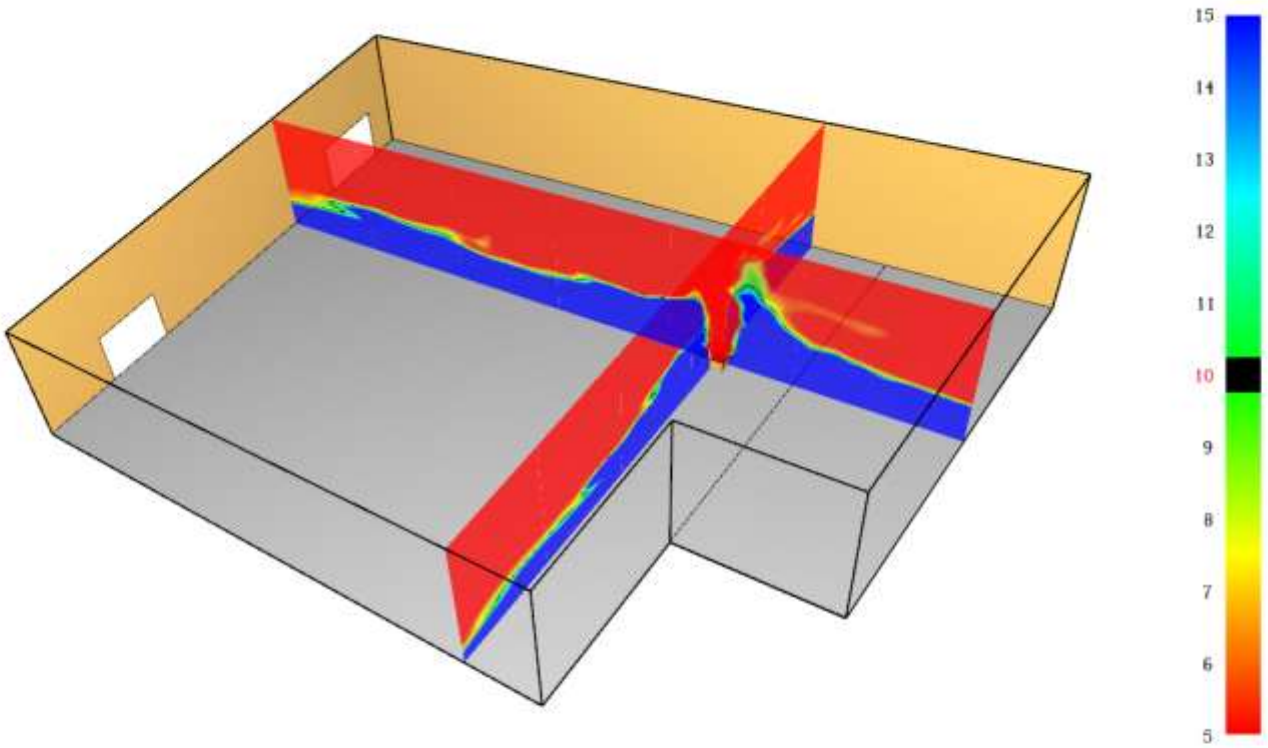
F.4.3 HP03C_8.6WD



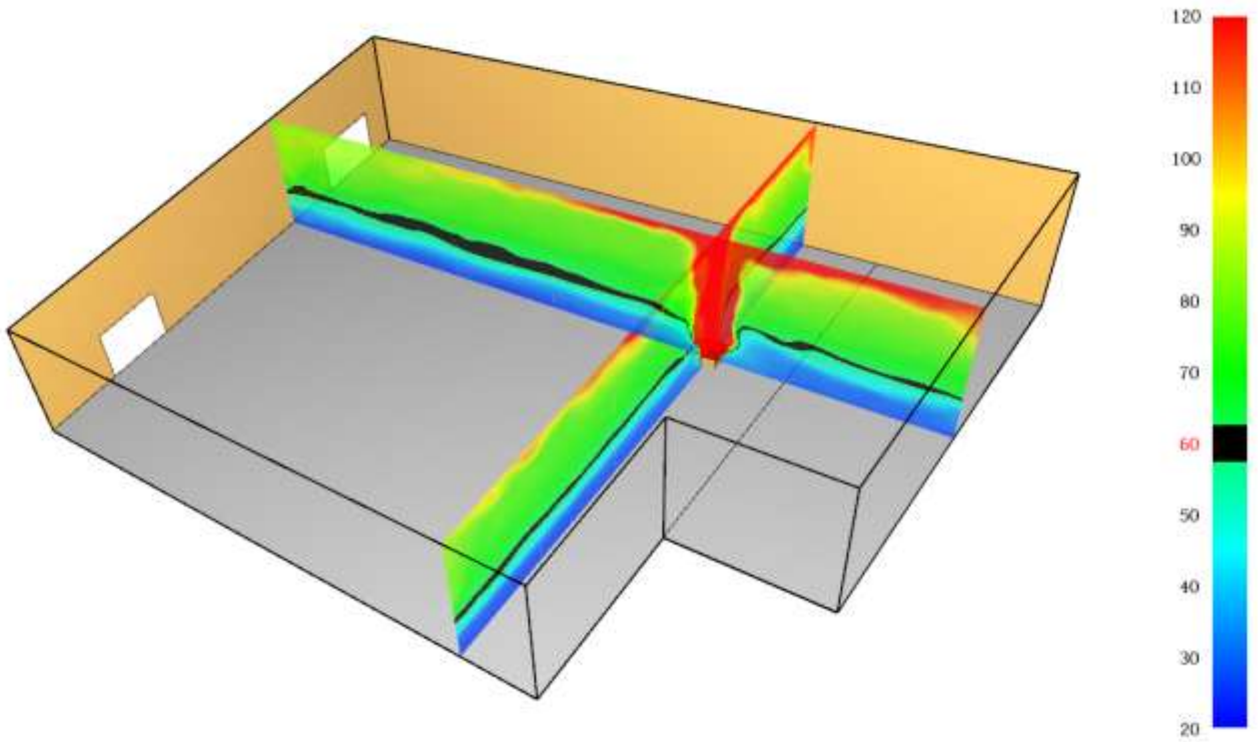
Visibility snapshot at 205 seconds (RSET)



Visibility snapshot at 308 seconds (1.5xRSET)

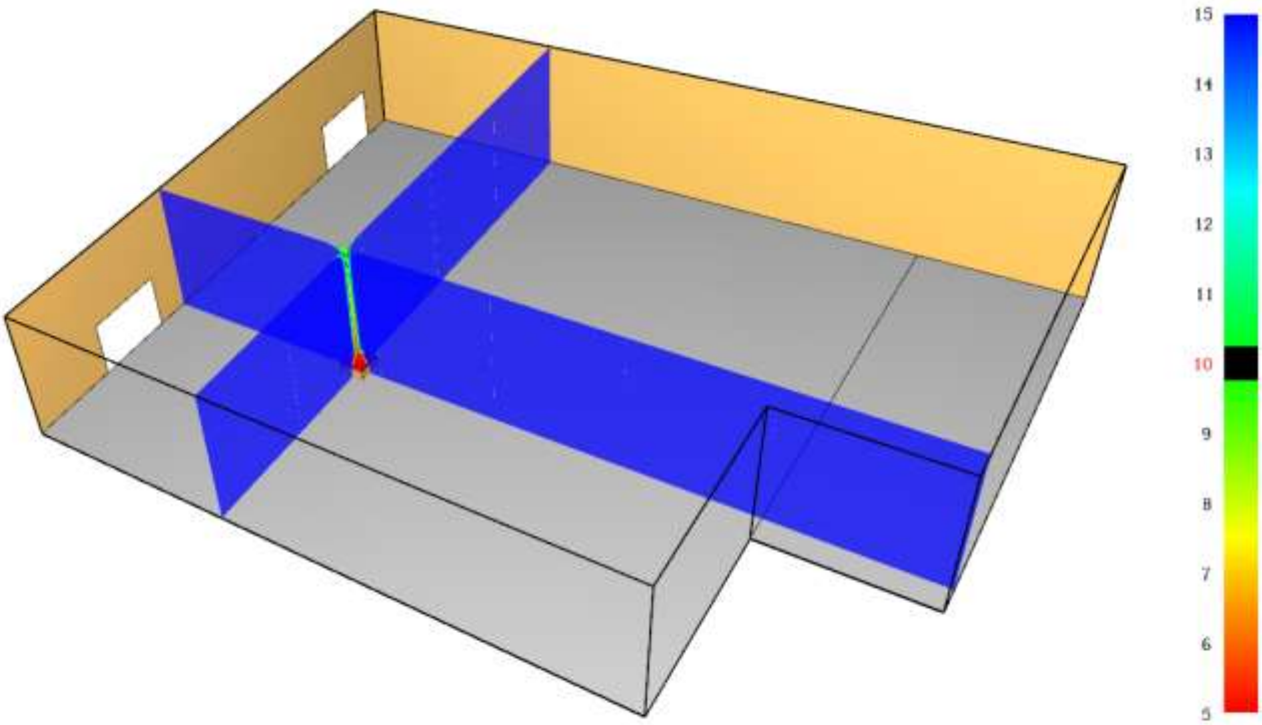


Visibility snapshot at 500 seconds (ASET)

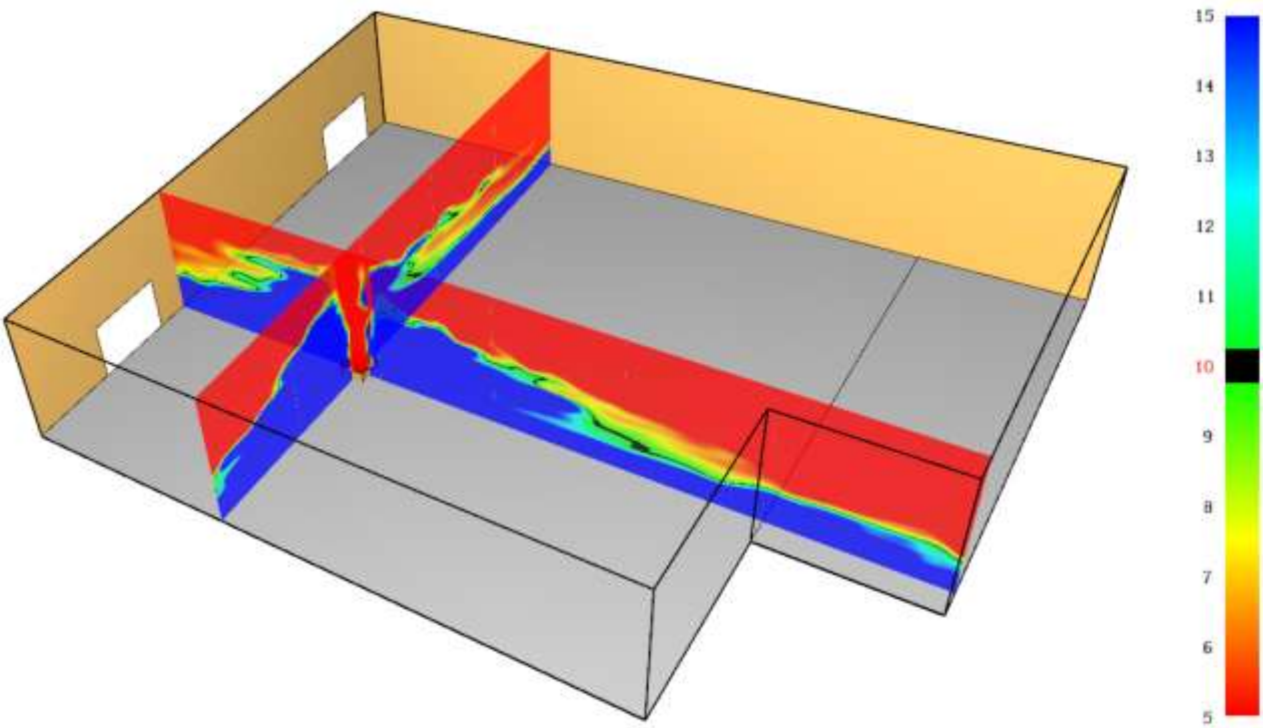


Temperature snapshot at 2700 seconds

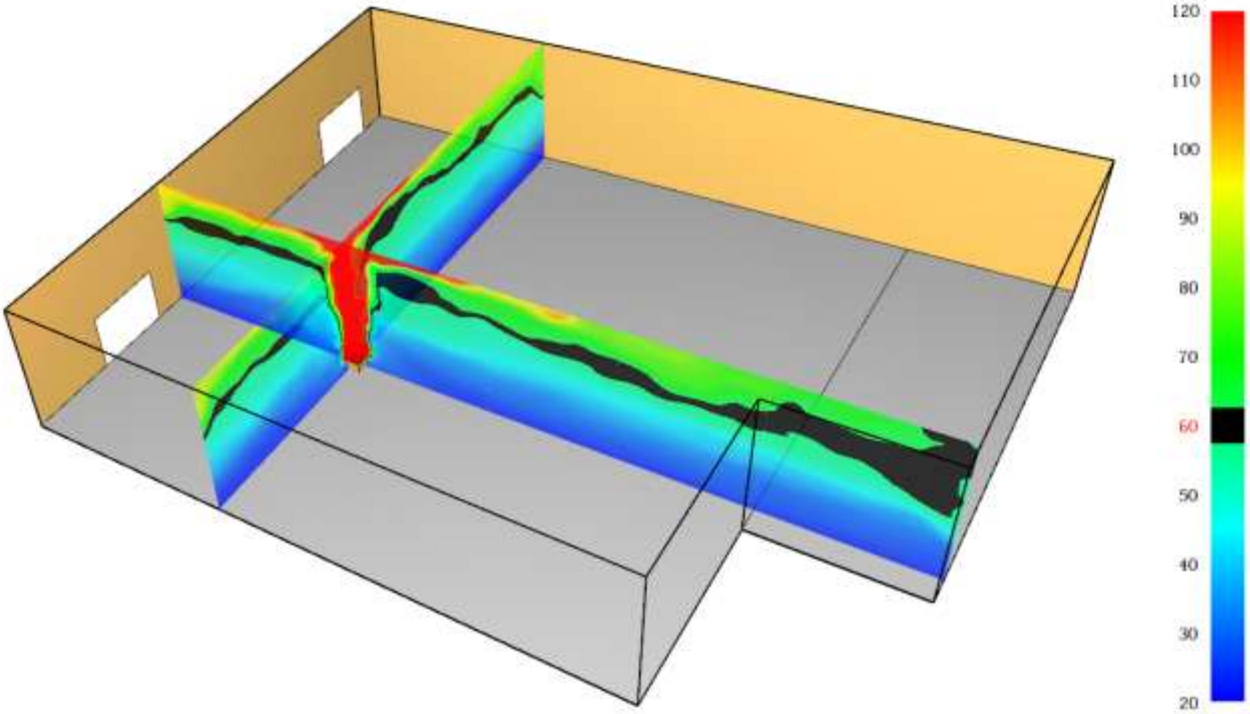
F.4.4 HP04S_8.7WS



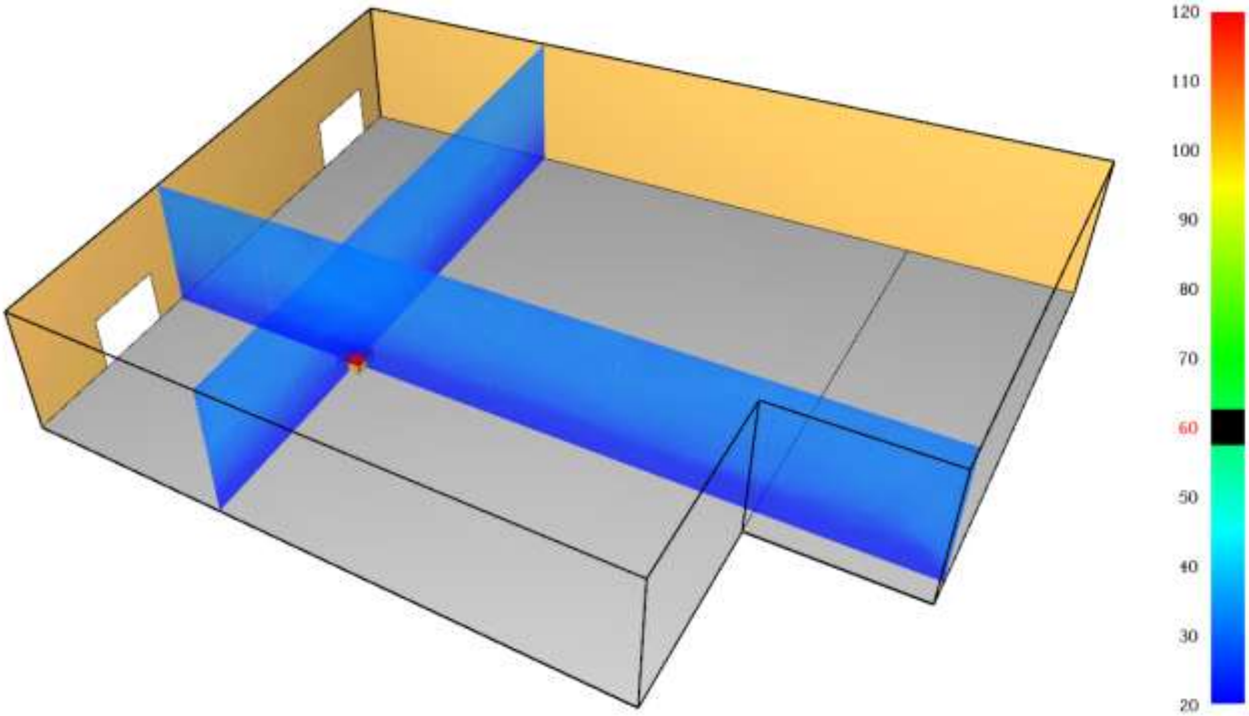
Visibility snapshot at 125 seconds (RSET)



Visibility snapshot at 825 seconds (ASET)



Temperature snapshot at 825 seconds (ASET)



Temperature snapshot at 2700 seconds

Appendix G. Occupant Movement Software (Pathfinder)

G.1 Pathfinder 3D Human Movement Simulation Model

The movement (or the floor clearing times) has been calculated using computer program Pathfinder. Pathfinder human movement simulation program is a validated and tested evacuation program. Pathfinder uses two primary options for occupant motion called SFPE mode and a steering mode. The SFPE mode implements the concepts in the SFPE Handbook of Fire Protection Engineering [Nelson and Mowrer, 2002]. This is a flow model, where walking speeds are determined by occupant density within each room and flow through doors is controlled by door width. The pathfinder computer program adopts the methodologies and principles outlined and based on actual research that has been conducted (IMO-Evacuation Analyses for New and Existing Passenger Ships). Pathfinder uses an occupant profile system to manage distributions of parameters across groups of occupants. This system helps you control the occupant speed, size, and visual distributions.

The alternate method in Pathfinder is the steering mode which is based on the idea of inverse steering behaviours. Steering behaviours were first presented in Craig Reynolds' paper "Steering Behaviours For Autonomous Characters" [Reynolds, 1999] and later refined into inverse steering behaviours in a paper by Heni Ben Amor [Amor et. al., 2006]. Pathfinder's steering mode allows more complex behaviour to naturally emerge as a by-product of the movement algorithms - eliminating the need for explicit door queues and density calculations. It is noted that in this instance the SFPE mode was incorporated in the Pathfinder simulation.

Pathfinder is an agent-based egress simulator that uses steering behaviours to model occupant motion throughout evacuation. It consists of three modules:

- The graphical user interface: and
- The simulator; and
- The 3D results viewer.
- **Current Pathfinder release version:** Pathfinder-2018-4-1210

G.2 Applications of the Pathfinder Software

In the Pathfinder evacuation modelling the occupants may be allocated profiles and behaviours. The profile defines characteristics of the occupants, such as speed, radius, avatar, and colour. The behaviour defines a sequence of actions the occupant will take throughout the simulation, such as moving to a refuge area, waiting or queuing at the exit, and then exiting.

Behaviours in Pathfinder represent a sequence of actions the occupant will take throughout the simulation. For each occupant behaviour in an evacuation model dedicated to agents there is an implicit action to move the occupant to an exit. This implicit action will always happen last. Additional intermediate actions may also be added in Pathfinder evacuation modelling can make the occupant wait or travel to a non-exit destination, such as a room or particular location on the floor plate. By default in the Pathfinder model the occupant behaviour is called “Go to Any Exit.” This behaviour type simply makes the occupant move from their starting position to any exit present in the model by the fastest route.

The SFPE mode uses the set of assumptions presented in the SFPE Handbook of Fire Protection Engineering and generally gives answers similar to hand calculations, depending on or if selected assumptions have been applied in the model. In SFPE simulations, the mechanism that controls simulation movement is the door queue, as queuing generally governs occupant evacuation. The Steering mode is more dependent on collision avoidance and occupant interaction for the final answer and often gives answers more similar to experimental data than the SFPE mode.

All occupants in Pathfinder use individual (or agent based) decision making algorithms. The model is a PC-based computer program capable of simulating the evacuation of large numbers of people through geometrically complex buildings.

G.3 Verification and Validation of the Pathfinder Software

Verification and Validation of the Pathfinder program have been documented by Thunderhead Engineering and Rolf Jensen & Associates Fire Protection Consultants (Document no: Pathfinder 2009.1.0417, Document Title: Verification and Validation). The aforementioned document has conducted the following:

- Verification tests: Synthetic test cases designed to ensure that the simulator is performing as specified by the Pathfinder Technical Reference. Usually these tests attempt to isolate specific simulated quantities or behaviours and may include only a small number of occupants. This type of test often has very specific pass/fail criteria. Verification tests ensure that the software is implements a particular model correctly –they are not designed to measure how accurately that model reflects reality.

- The document has documented eleven (11) IMO (International Maritime Organization) Tests which have demonstrated satisfactory results. These tests are listed below:
  - Movement speed, and
  - Stairway speed (Up), and
  - Stairway speed (Down), and
  - Door flow rates, and
  - Initial delay times, and
  - Concave geometry (Boundaries), and
  - Multiple movement speeds, and
  - Counter flow, and
  - Sensitivity to available doors, and
  - Exit assignments, and
  - Congestions.
- Validation tests – Designed to measure how well Pathfinder's implementation of simulation models captures real behaviour. Usually these tests will explore the interaction between multiple simulations elements and may have less specific pass/fail criteria. Validation tests are usually based on experimental data or experience.
- Comparisons – Pathfinder results alongside the results of other simulators. These tests are design to give the reader a sense of where Pathfinder "fits in" relative to other simulation software.

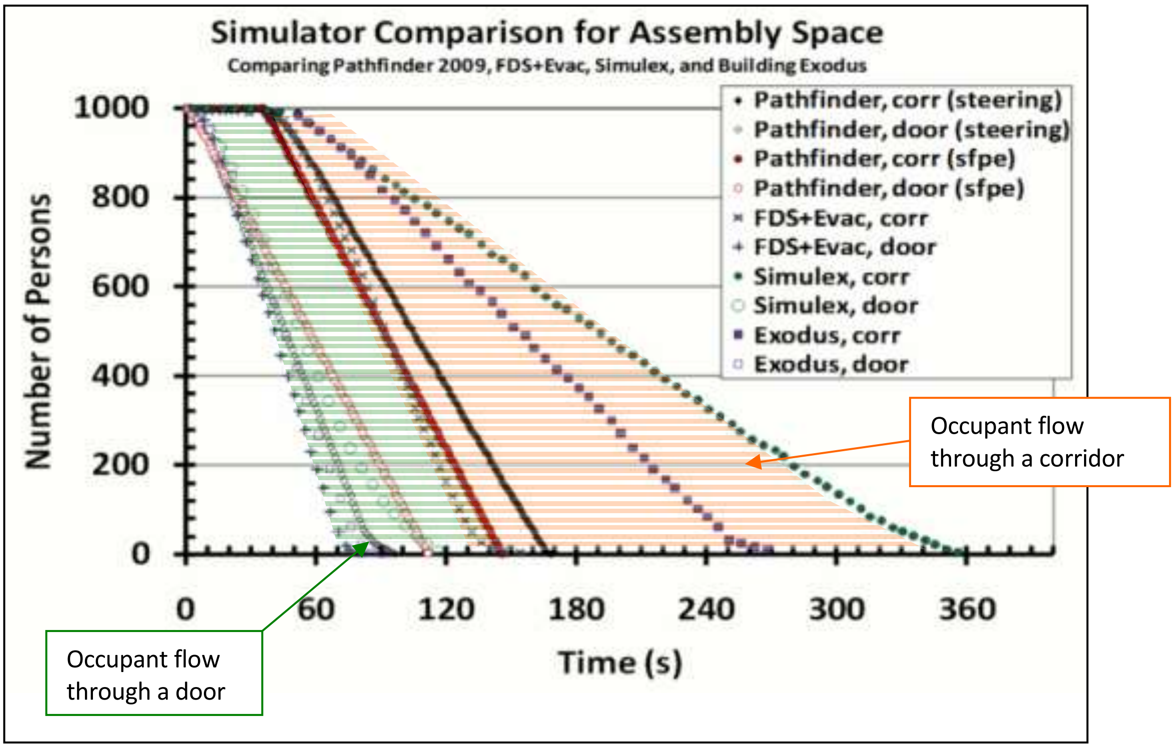


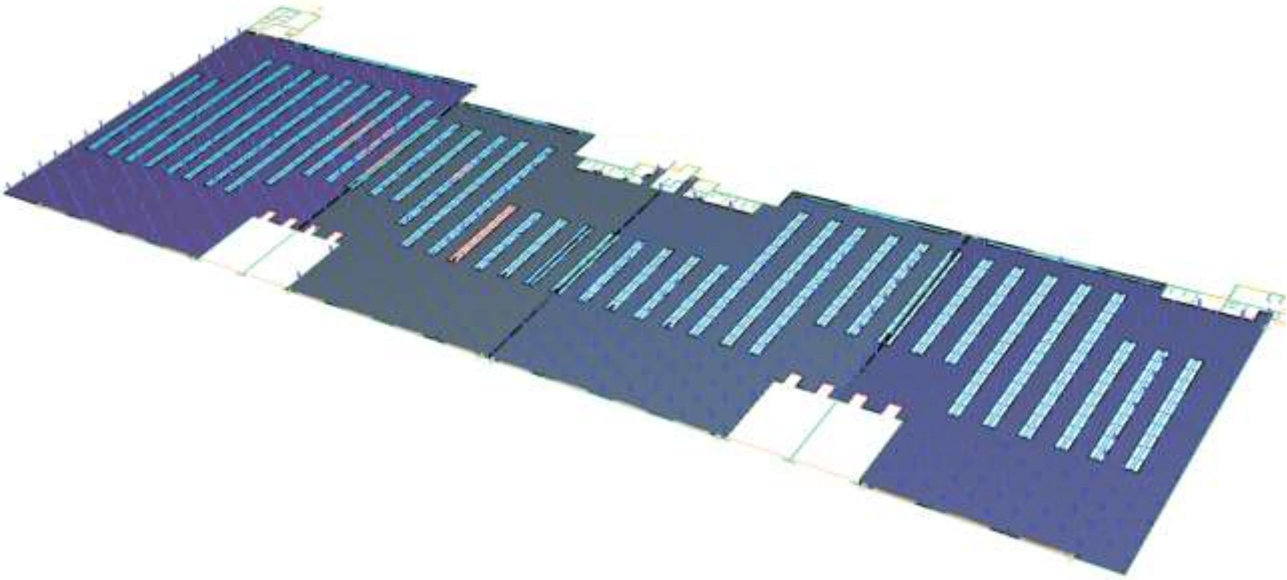
Figure G.1: Occupant movement simulator comparisons between different software.

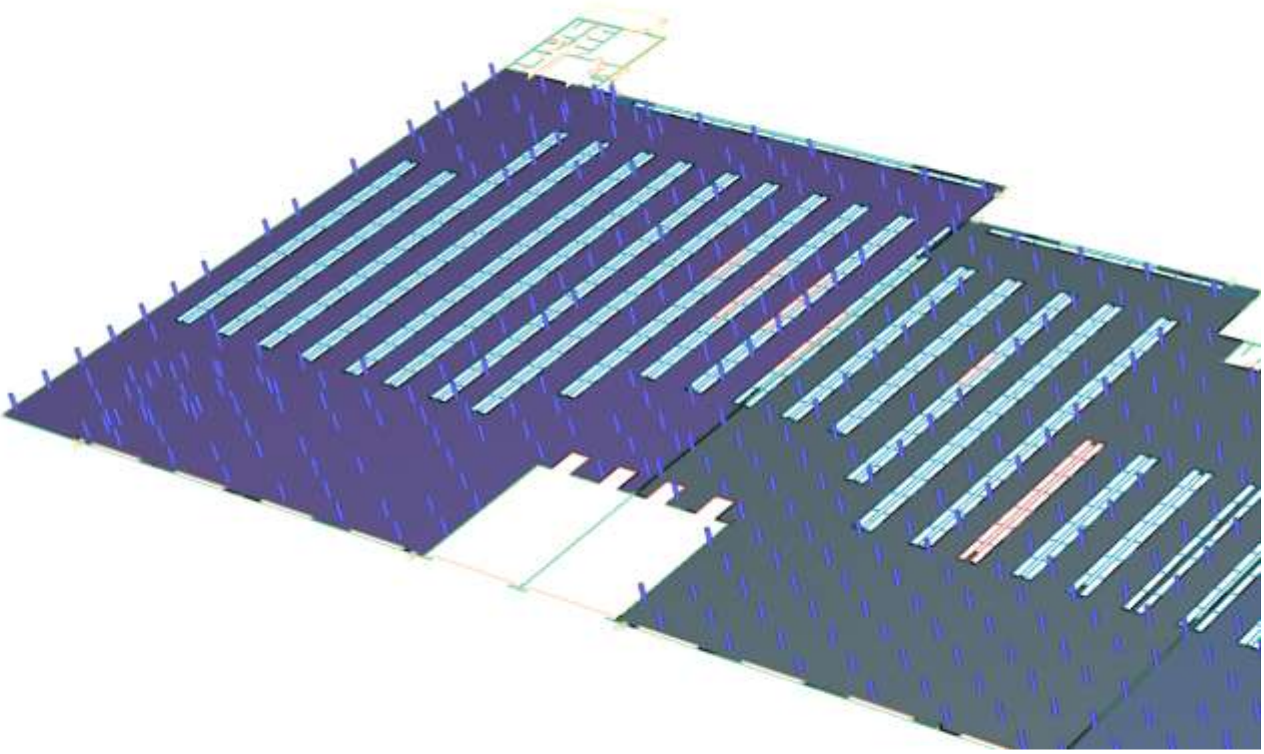
G.4 Occupant Risk Contour Approach

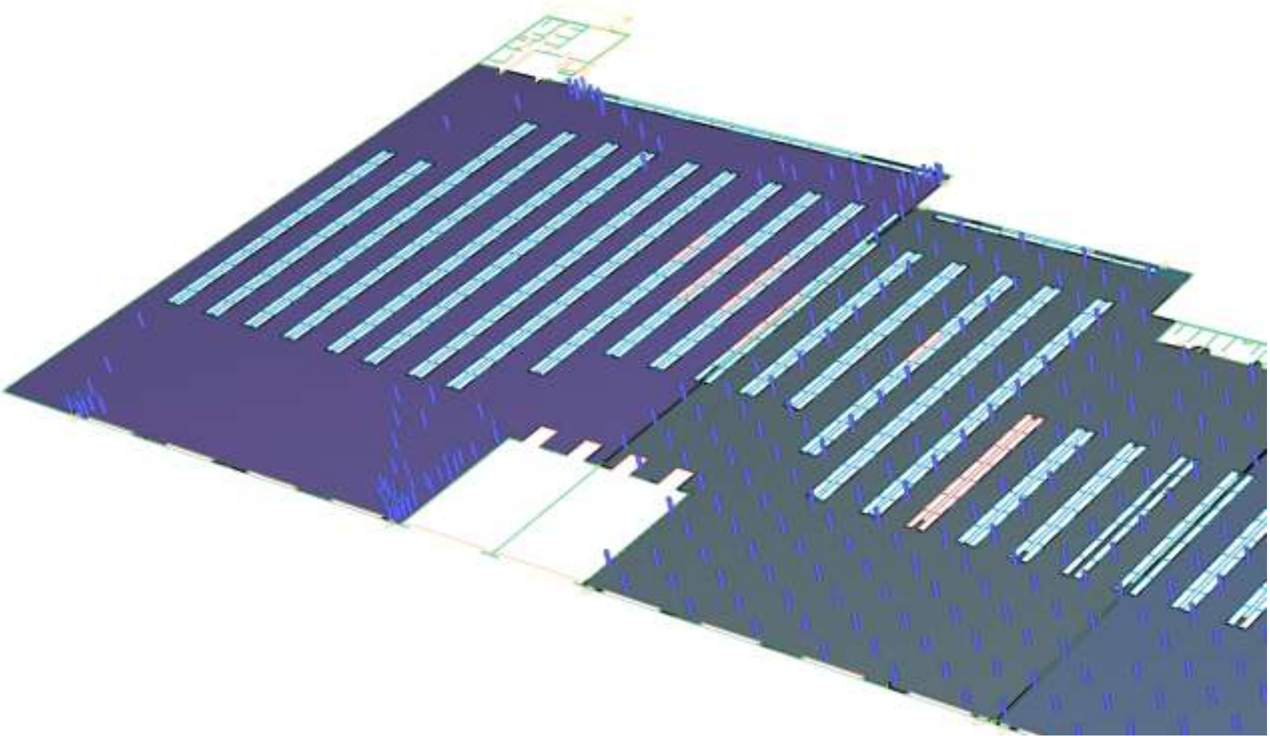
The risk contour approach is the concept methodology (Horasan, Kilmartin 2009) which has been adopted in this instance for the evacuation modelling. This concept has also been adopted and reflected by the New Zealand Department of Building and Housing as part of the Building Codes in the document titled "C/VM2 Verification Method: Framework for Fire Safety Design For New Zealand Building Code Clauses C1-C6 Protection from Fire".

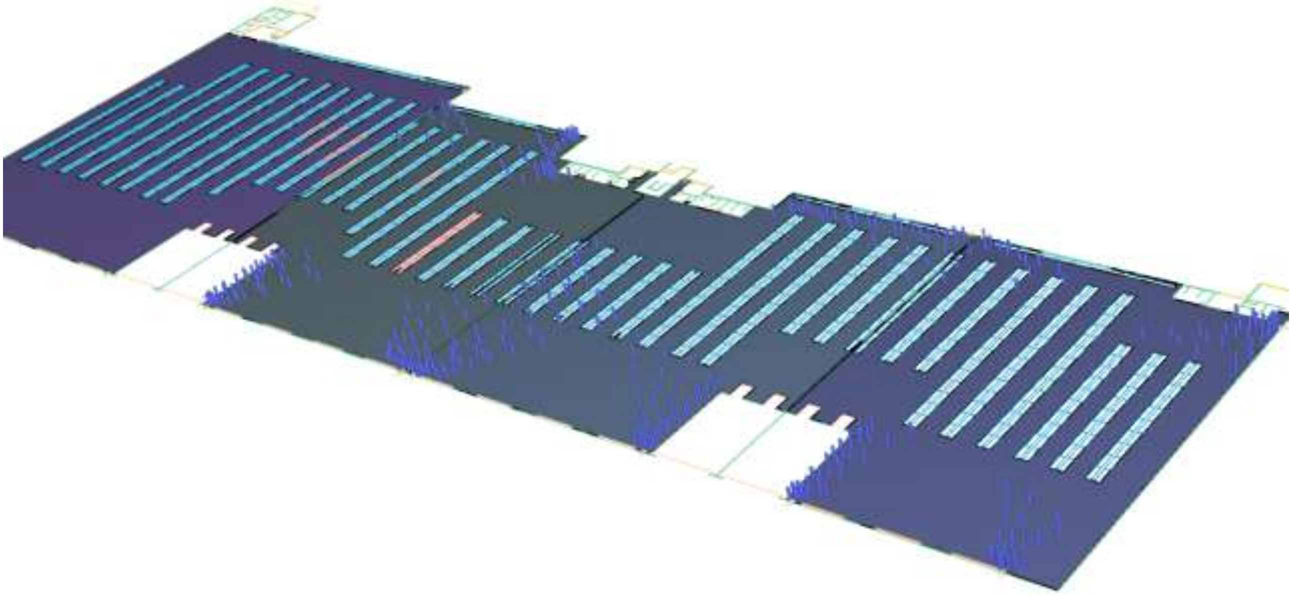
It is important to highlight that the evacuation modelling forming part of the overall Life Safety Analysis was performed utilising the 'Pathfinder' computer software program. The 'Pathfinder' computer software program was used to compute the cumulative time for both **pre-movement and movement times**. Verification and Validation of the Pathfinder program has been documented by Thunderhead Engineering and Rolf Jensen & Associates Fire Protection Consultants.

G.5 Pathfinder Geometry









G.6 Pathfinder Results

G.6.1 Geometry

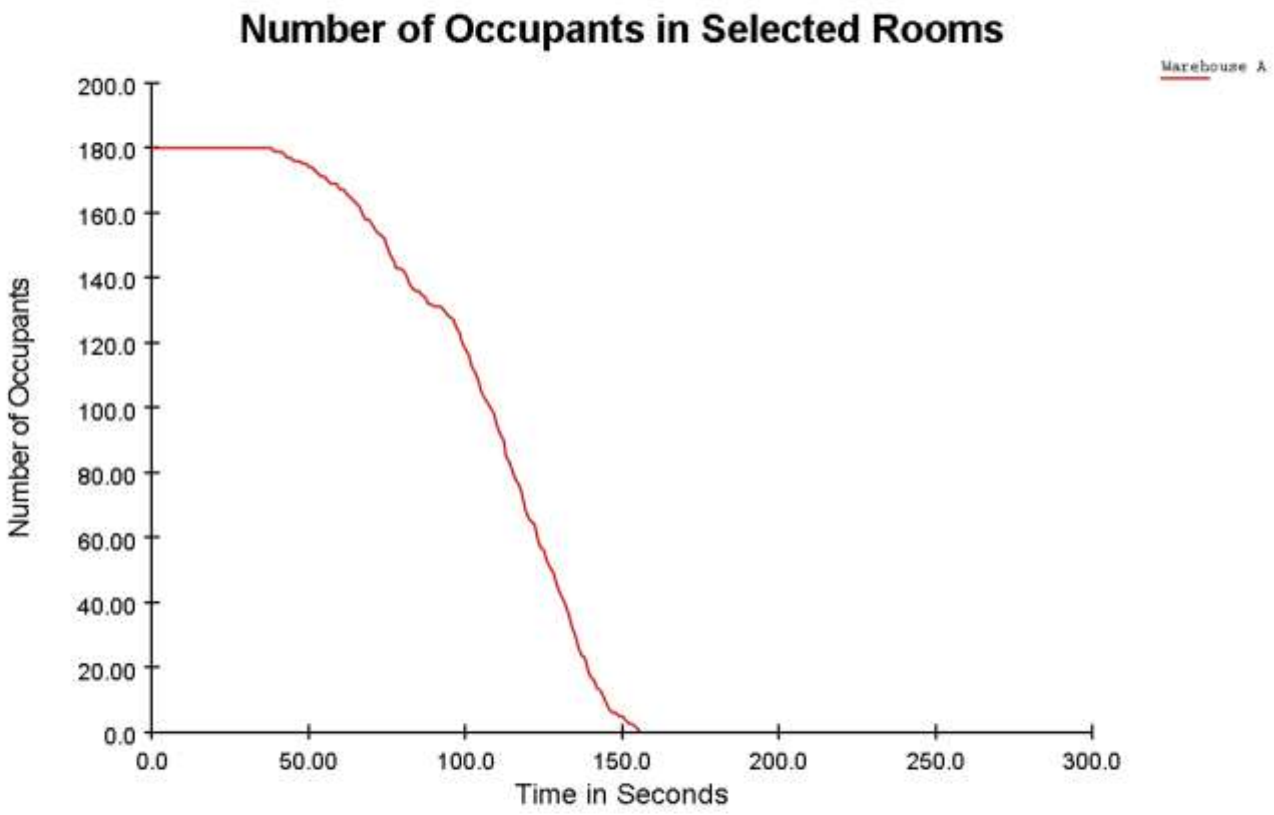


Figure G.2: Evacuation time for occupants in Warehouse A – ES01C

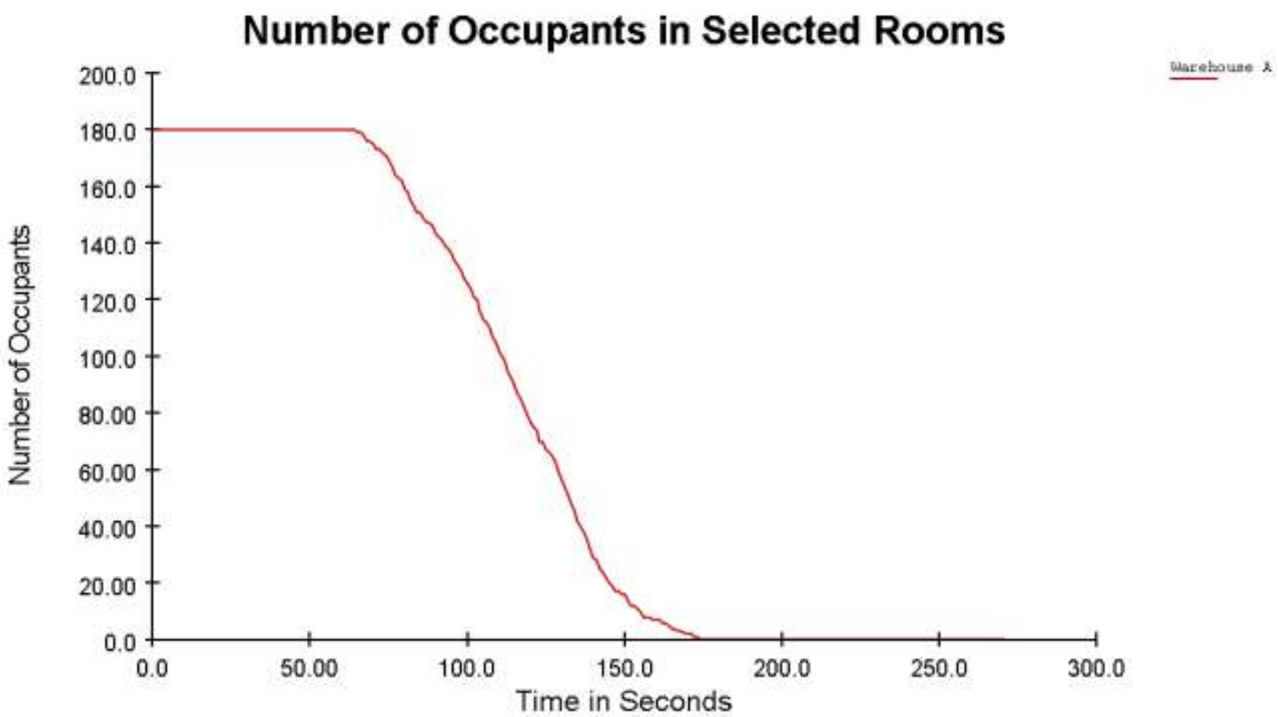


Figure G.3: Evacuation time for occupants in Warehouse A – ES01S

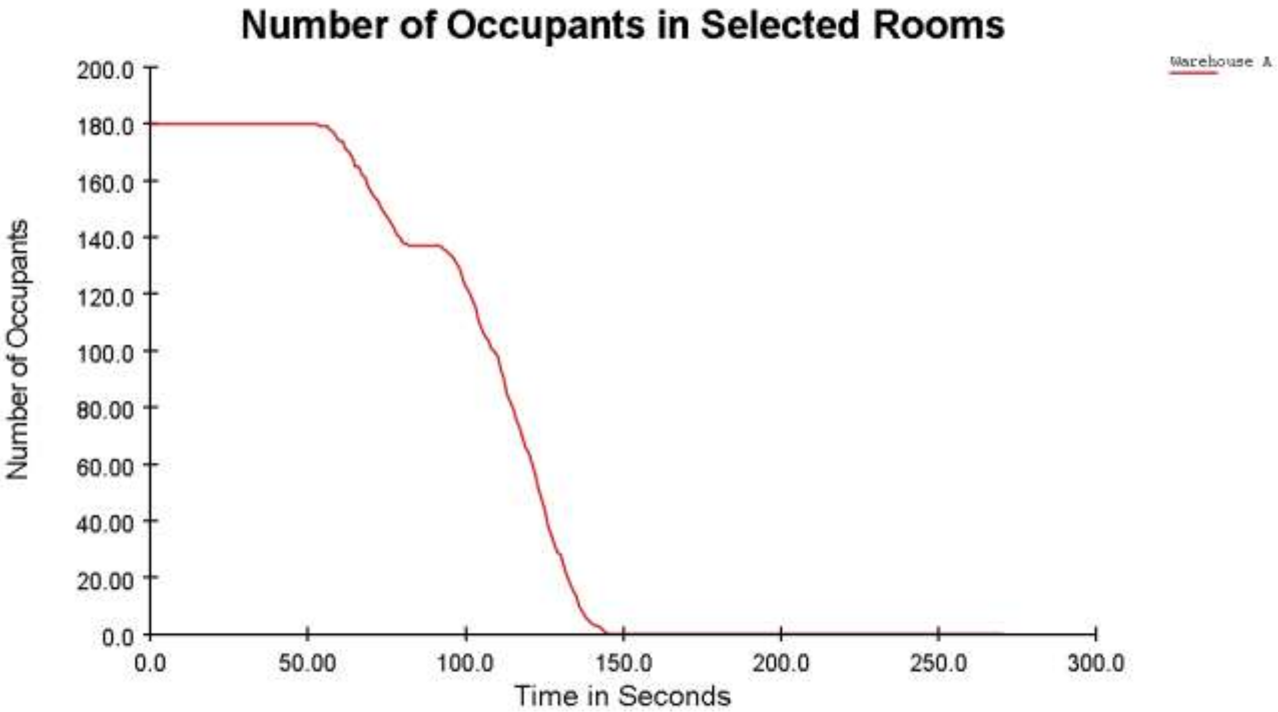


Figure G.4: Evacuation time for occupants in Warehouse A – ES02C

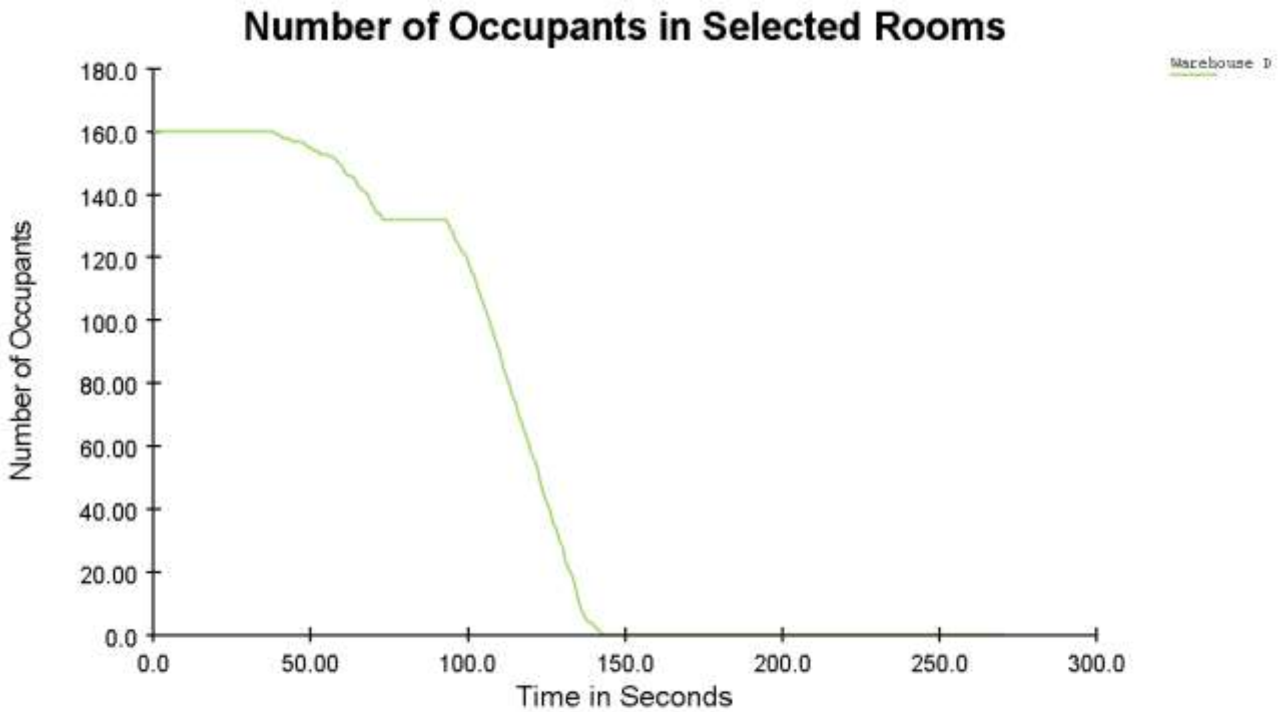


Figure G.5: Evacuation time for occupants in Warehouse D – ES03C

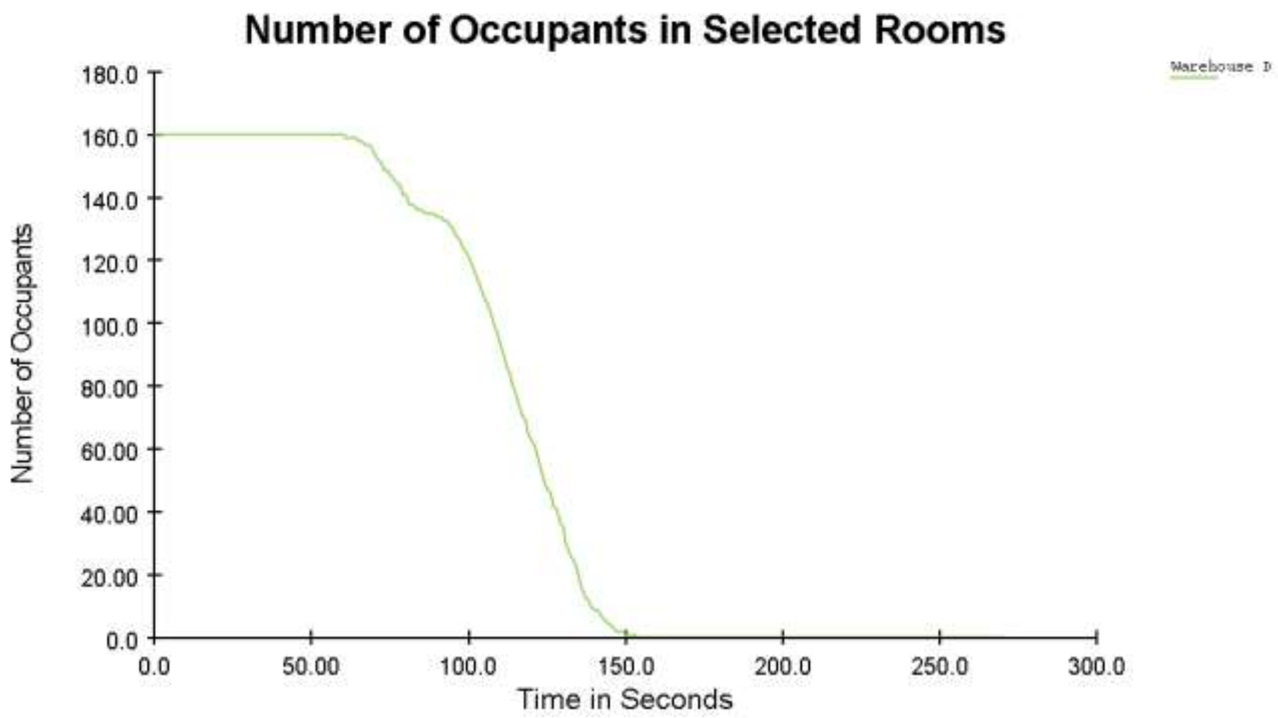


Figure G.6: Evacuation time for occupants in Warehouse D – ES03S

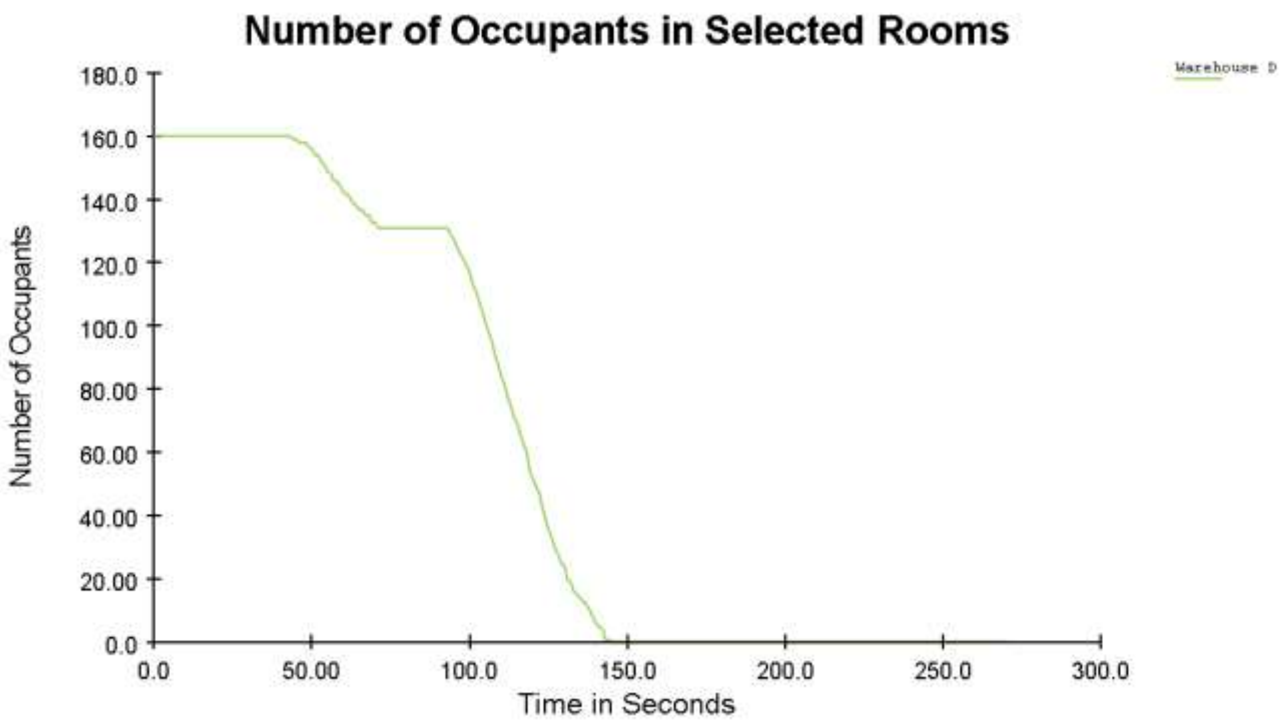


Figure G.7: Evacuation time for occupants in Warehouse D – ES04C

Appendix H. Design Fire Documentation & Justification

H.1 General Overview

Design fires are to be adopted for each of the proposed fire scenarios that have been identified as most appropriate for the subject centre. Each design fire must have consideration for the fuel loads its orientation and the amount of ventilation. Fuel controlled fires represent the principal design fires for those areas not protected with automatic sprinklers (high ceiling level areas etc). The principal form of intervention considered in the fire and smoke modelling assessment is that of occupant or fire fighter suppression activities. It should be noted that the building is to be installed with a sprinkler system and therefore, it is more likely that within areas where sprinkler protection has been afforded the sprinklers will automatically operate and effectively control any potential fire. Extensive studies carried out by a number of experts (including Marryatt) covering the past century of sprinkler protected buildings have confirmed that these systems are inherently reliable if well maintained and managed.

It is unrealistic to adopt a single fire that represents the extreme worst case as the principal design fire and apply it to all fire scenarios required to be modelled. It is considered that systems appropriately design commissioned and maintained would work as designed and hence the worst-case design fire would be a fire that did not take into account such systems. For example, in a building with sprinklers, the principal design fire would not be that in which sprinkler system failure is assumed. This scenario would be considered but the tenability criteria adopted for the assessment of this scenario may be less conservative than that adopted for the sprinkler affected fires. Using the worst-case scenario as the controlling design fire would lead to unacceptable and extremely conservative designs. Assessments conducted to consider the potential impact of fires which are more severe than the principal design fire may be used to assess the sensitivity of the performance solutions applied.

The design fire for any location is therefore considered the *worst credible* fire size given the nature of the fuel type and disposition and elements being assessed. Whilst there is a large amount of information concerning the burning rate of items, rarely is this information sufficiently generic to be universally adopted and what may be representative of current fuel loadings may not be the case in years to come. In any event it would be a rare assessment in which the specific items forming the fuel load had been tested to provide fire rate of heat release data.

Much experimental work has been carried out on the burning rates of items. These have been closely examined and translated into a simplified mathematical expression relating heat release rate with time after commencement of the flaming stage of fire growth. The unpredictable incubation phase of fire development is not included. The basis of the mathematical simplification arises from the fact that the fire growth during the flaming stage can be approximated by a smooth curve which can be expressed mathematically.

It should be noted that this data is determined from test fires in which there is an adequate supply of air. The fire is not ventilation controlled and neither is there the radiant heat feedback into the burning item that occurs when a fire occurs in an enclosure with a ceiling. In this latter case, the hot smoke retained in the enclosure provides a radiant heat source to the fuel which may significantly change the burning rate from that determined during a test fire.

The growth rates of fires used in the modelling of smoke and fire spread can be conveniently defined by a quadratic equation of the form:

$$Q = (t/k)^2$$

where

Q = is the rate of heat release (MW)

k = is a constant, the fire growth parameter (MW/sec^2)

t = is the time after ignition of the fire (seconds)

The continued growth of a fire defined by the above equation relies on a sufficient source of fuel and air and further assumes that flashover has not occurred within the fire compartment or that any suppression measures have been employed.

Studies of actual fire tests has led to the adoption of four standard fire growth rates covering a wide range of potential fire scenarios and fuel loads. The four standard fire growth rate models are those presented below:

'Ultrafast' where k = 75

'Fast' where k = 150

'Medium' where k = 300

'Slow' where k = 600

As noted, the times of the fire incubation period are not included in the use of the t^2 fire growth models to predict fire size over time. Figure H.1 illustrates typical fire growth rates.

The design fire curve represents the initial stages of a fire. For each scenario the design fire is modified to take into account either the action of fire suppression measures or the reduction of available fuel or lack of ventilation. These scenario fires are used in the computer models to determine the smoke spread between the enclosures or as the basis for assessing structural and barrier requirements.

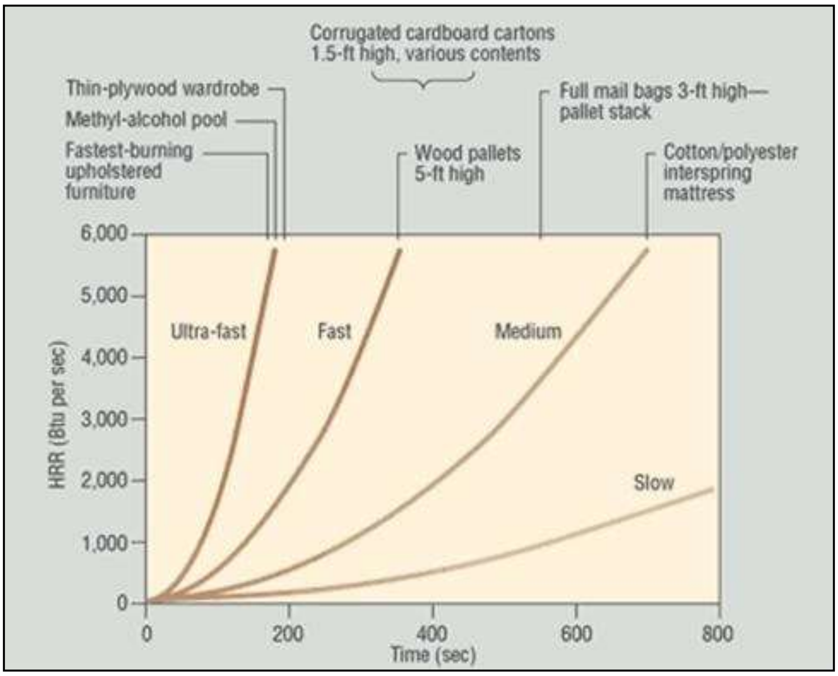


Figure H.1: Different t^2 Design Fires (based on test data)

H.2 Project Specific Design Fire Justification

It should be noted that the design fires were calculated using a number of calculations. The sprinkler activation times were found using an excel spread sheet model which incorporates formulas that have been referenced in R.L. Alpert Fire Technology 1972 pp181-195. The program computes the thermal response of a sprinkler head located near the ceiling where the ceiling is assumed to be unconfined.

The storage sprinkler head activation is based on the Viking ESFR Pendent Sprinkler (K22) or equivalent (refer to Appendix D) which was calculated using a Response Time Index (RTI) of $50m^{-0.5}s^{-0.5}$ and an actuation temperature of 96°C. Storage sprinkler heads can be supplied with a temperature rating of 93°C however as a conservative measure, 100°C has been utilised as the actuation temperature. Storage sprinkler systems are designed for use with storage heights of up to 12.2m and maximum ceiling heights of 13.7m.

As the building is fitted with storage type sprinkles the core fire scenarios consist of fires that are controlled by the activation of sprinklers. In the scenario where sprinklers fail to activate or control the fire, the fire detection system becomes the means of visual detection and furthermore, the fire growth rate continues to increase to represent fuel-controlled burning.

H.2.1 Project Specific Design Fires

The project specific design fires are based on the following incidents:

1. Electrical malfunction such as with electrical lighting igniting combustible goods within storage racking arrangement.
2. Mechanical failure or malfunction (e.g. malfunction of a forklift) igniting nearby stored contents within the racking arrangement.

H.3 HP01C_8.6WA and HP03C_8.6WD Sprinkler Controlled Fire – Storage Rack Fire (Core)

H.3.1 Ultra-Fast t^2 Fire Growth Rate

The adopted design fires within the sprinkler protected areas shall be based on the time at which the installed sprinkler system activates and hence impacts on the fire growth. The times adopted for sprinkler activation (time after ignition at which the fire would be controlled) within the subject warehouse shall be based upon the type of sprinkler heads installed, the location of the sprinkler heads above the finished floor level and the spacing of the sprinkler heads from each other.

For this fire scenario it is assumed that the storage sprinklers, as per their design specifications, would suppress and eventually extinguish the fire. The input to the sprinkler activation time model was based on the following specifications:

- Sprinkler Head Type:
  - Actuation Temp = 100°C, RTI = $50m^{0.5}s^{0.5}$
- Height Above the Finished Floor Level:
  - Maximum height above the finished floor level is 13.7m (to the ridge line)
- Sprinkler Head Spacing and distance of sprinkler from the axis of fire:
  - 3.1m x 3.1m grid ($9.6m^2$); R = 2.2m.
- Fire Growth Rate:
  - Ultra-Fast t^2 fire conservatively based on the presence of a wide range of goods stored within the storage racks.

The HP01C_8.6WA and HP03C_8.6WD fire scenarios shall assume that the first ring of sprinklers would activate, control and eventually extinguish the fire.

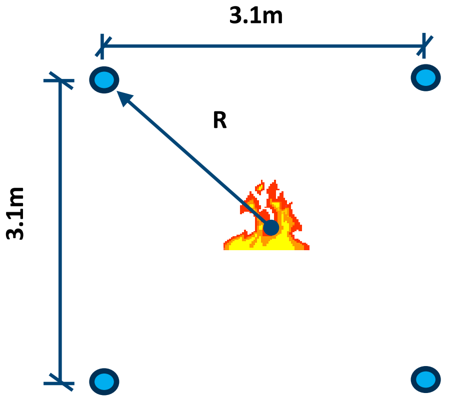


Figure H.2: First Ring of Sprinklers

The following illustrates the input to and the output from the sprinkler activation time calculations.

Alpert's Correlation

Required Inputs	
Ambient Temperature, T =	20 (°C)
Fire Growth Rate =	Ultrafast
Time Step Interval =	20 (s)
Radial Distance of the Detector from the Fire, r =	2.2 (m)
The Height of the Ceiling above the fire, H =	13.7 (m)
The Response Time Index of the Detector, RTI =	50 ($m^{1/2}s^{1/2}$)
Sprinkler Density of Discharge =	5 mm / min
Sprinkler Activation Temperature =	100 (°C)
Calculated Quantites at Detector Activation	
The Gas Temperature at Sprinkler Activation, T =	108.83 (°C)
HRR at Sprinkler Activation =	8371.38 (kW)
The Gas Velocity, U =	7.60 (m/s)
Time at Sprinkler Activation =	218 (s)
Time to Reach 10% of peak HRR =	904 (s)
Ratio, r / H =	0.16

Illustration

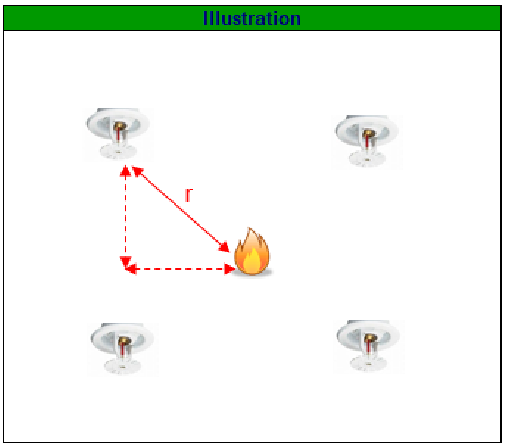


Figure H.3: Activation of sprinklers for HP01C_10.4W1 and HP03C_10.4W3

The peak heat release rate has been calculated (at the time of sprinkler head activation) to be in the order of **8.6MW**.

H.4 HP02S_16.5WA Sprinkler Controlled Fire – Storage Rack Fire (Sensitivity)

H.4.1 Ultra-fast t^2 Fire Growth Rate

The adopted design fire within the sprinkler protected storage area shall be based on the time at which the installed sprinkler system activates and hence impacts on the fire growth. The time adopted for sprinkler activation (time after ignition at which the fire would be controlled) within the subject warehouse shall be based on the type of sprinkler heads installed, the location of the sprinkler heads above the finished floor level and the spacing of the sprinkler heads from each other.

For this fire scenario it is assumed that the storage sprinklers, as per their design specifications, would suppress and eventually extinguish the fire. The input to the sprinkler activation time model was based on the following specifications:

- Sprinkler Head Type:
  - Actuation Temp = 100°C, RTI = $50m^{0.5}s^{0.5}$
- Height Above the Finished Floor Level:
  - Maximum height above the finished floor level is 13.7m (to the ridge line)
- Sprinkler Head Spacing and distance of sprinkler (second ring) from the axis of fire:
  - 3.1m x 3.1m grid ($9.6m^2$); R = 4.9m – based on second ring of sprinklers activate.
- Fire Growth Rate:
  - Ultra-Fast t^2 fire conservatively based on the presence of a wide range of goods stored with the storage racks.

The HP02S_16.5WA scenario shall assume that the second ring of sprinklers would activate and at least control the fire.

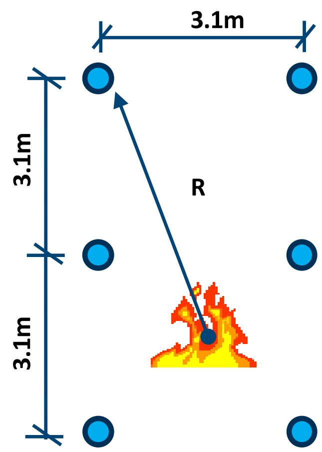


Figure H.4: Second ring sprinkler activation

The following illustrates the input to and the output from the sprinkler activation time calculations.

Alpert's Correlation

Required Inputs	
Ambient Temperature, T =	20 (°C)
Fire Growth Rate =	Ultrafast
Time Step Interval =	20 (s)
Radial Distance of the Detector from the Fire, r =	4.9 (m)
The Height of the Ceiling above the fire, H =	13.7 (m)
The Response Time Index of the Detector, RTI =	50 ($m^{1/2}s^{1/2}$)
Sprinkler Density of Discharge =	5 mm / min
Sprinkler Activation Temperature =	100 (°C)
Calculated Quantites at Detector Activation	
The Gas Temperature at Sprinkler Activation, T =	107.97 (°C)
HRR at Sprinkler Activation =	16429.51 (kW)
The Gas Velocity, U =	4.88 (m/s)
Time at Sprinkler Activation =	305 (s)
Time to Reach 10% of peak HRR =	991 (s)
Ratio, r / H =	0.36

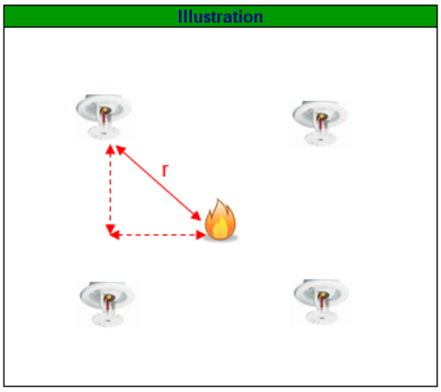


Figure H.5: Activation of sprinklers for HP02S_18.6W1

The peak heat release rate has been calculated (at the time of sprinkler head activation) to be in the order of **16.5MW**.

H.5 HP04S_8.7WD: Fuel Controlled Fire – Forklift & Storage Pallet Fire (Sensitivity)

H.5.1 Description of Fire Scenario

As part of the warehouse process within the warehouse facility a number of electrically powered forklifts are expected to be operating within this part of the building. Whilst it is unclear how many industrial fires are caused by forklift ignition sources and accidents, these fires are nonetheless well represented in the statistics and as such are relevant to the assessment for the subject premise. The forklifts are primarily used to transport goods. At times these goods may be stored on pallets (i.e. timber storage pallets). In this instance, a core fire scenario has been developed whereby a forklift fire shall initiate before spreading to a nearby storage/racking arrangement where additional combustibles are located. Published research material, a degree of engineering judgement and assumptions have been adopted to quantify the time when fire from the forklift is likely to spread to the stack of wooden pallet.

H.5.2 Fire Growth Rate – Forklift Fire

Rate of Heat Release (RHR) for a forklift can be similarly compared to a potentially small car fire. Free burn test data compiled by Lund University has been published with a small car fire being undertaken. The car used in the fire test was an ordinary sedan passenger vehicle and the RHR for the test is depicted as per the following:

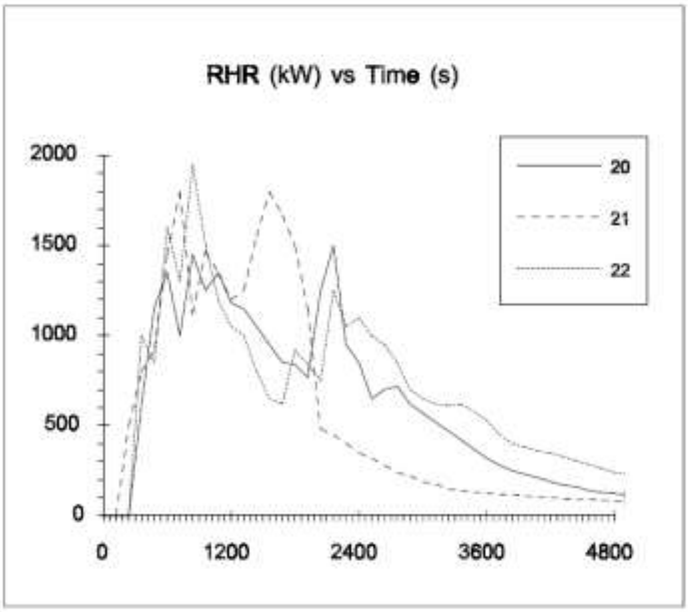


Figure H.6: RHR – Small car

As illustrated above, a total of three (3) tests were undertaken as denoted by Test 20, 21 & 22.

- Sample 20- Fuel burnt from the mouth of the filler pipe;
- Sample 21- Fuel burnt from the mouth of the fuel tank and from a pool under the car, when the filler pipe and fuel hose melted;
- Sample 22- Fuel burnt from the mouth of the fuel tank, when the filler pipe melted.

As per the above, there is a considerable incubation period whereby the rate of heat release during the first 300-400 seconds is considered minimal. Based on the heat release rate curve results, 1MW is reached beyond 300 seconds and therefore, the fire growth curve is considered conservatively to be a medium t^2 fire growth rate.

Utilising the medium t^2 fire growth rate determined above, it can be assumed that the peak heat release rate for a credible vehicle (forklift) fire scenario can follow the medium fire growth rate however reach a peak heat release rate of **2.5MW (Q)** (fuel controlled) as per the PIARC recommendations.

H.5.3 Fire Growth Rate – Timber Storage Pallet Fire

According to the table below, it can be seen that the growth time (i.e. growth time to reach 1MW) is between 60-190 seconds for typical stacked combustible goods. Based on the data in the table below, timber pallets stacked 3.0m high may take up to 80-110 seconds to reach 1MW which is approximately representative of a fast to ultra-fast t^2 fire growth rate. Despite the mean k-factor, a conservative approach would be to consider an ultra-fast t2 fire growth rate which is calculated to reach 1MW in 75 seconds (being close to a k-factor of 80).

For the purposes of this analysis, an ultra-fast t^2 fire growth rate would conservatively be considered to be the minimum fire growth rate for an industrial/warehouse building reaching a peak heat release rate (PHRR) of 6.8MW.

Table H.1: Peak Heat Release Rate and Time data for Industrial Commodity obtained from Furniture Calorimeter Tests

Industrial Commodity	Growth Time (k value) (seconds)	Peak Heat Release Rate Density (MW/m^2)
Wood Pallets, stack, 0.45m high (6%-12% moisture)	150-310	1.2
Wood Pallets, stack, 1.5m high (6%-12% moisture)	90-190	3.7
Wood Pallets, stack, 3.0m high (6%-12% moisture)	80-110	6.8
Cartons, compartmented, stacked 3m high	60	2.3

Based on the data tabulated above, it can be expected that a timber pallet storage fire (i.e. up to 3.0m high) will achieve an ultra-fast t^2 fire growth rate whilst achieving a peak heat release rate (PHRR) of **6.8MW (Q)** (fuel controlled).

H.5.4 Stead State Condition – Forklift Fire

In this instance, the forklift is assumed to burn for a period of time reaching its peak heat release rate (PHRR) before decaying. Utilising the test data presented above, the result for Sample 22 shows an instant drop in heat release rate once the PHRR is achieved. For the purposes of this design fire, a 100 seconds steady state period has been adopted prior to fire spreading to the stack of timber storage pallets.

H.5.5 Steady State Condition – Timber Storage Pallet Fire

In this instance, the storage pallet is assumed to burn for a period of time reaching its peak heat release rate (PHRR) before decaying. Free burn test data compiled by Building and Fire Research Laboratory (American Institute of Aeronautics and Astronautics, 2000) has been published for a timber pallet fire as presented above. A free burn test is suitable in this instance due to the building having a large volume which is similar to a free burn environment.

The results show that the time between PHRR (i.e. t_{io}) and the commencement of the decay phase (i.e. t_d) is approximately 30 seconds. For the purpose of this design fire, a conservative 100 seconds steady state period has been adopted.

TABLE C. Heat Release Rate vs Time in t^2-fire Characterization of Building and Fire Research Laboratory Data

	CODE	DESCRIPTION	t_0	$t_{1\,MW}$	t_{lo}	t_d	t_{end}	$\dot{Q}_{max}$	t_g	α_g	α_d
Fig. C1.	Bunk Bed	BFRL* in February 1996.	186	211	240	240	445	4665.6	25	1.600000	0.111020
Fig. C2.	Koisk	Western Fire Center in the summer of 1995.	817	1129	1230	1230	3300	1752.2	312	0.010273	0.000409
Fig. C3.	Loveseat		48	222	350	371	866	3012.4	174	0.033029	0.012294
Fig. C4.	Mattress (Center)	BFRL in February 1996.	9	173	145	219	959	687.7	164	0.037180	0.001256
Fig. C5.	Mattress (Corner)	BFRL in February 1996.	85	294	295	321	484	1009.6	209	0.022893	0.037999
Fig. C6.	Small Dresser	BFRL in February 1996.	112	346	423	423	870	1766.4	234	0.018263	0.008840
Fig. C7.	Sofa		26	222	390	399	931	3449.0	196	0.026031	0.012186
Fig. C8.	Wooden Pallet	BFRL in February 1996.	0	467	634	664	1616	1843.1	467	0.004585	0.002034
Fig. C9.	Workstation (2 panels)	Sponsored by GSA** and performed at BFRL in 1991.	132	244	280	280	3276	1746.2	112	0.079719	0.000195
Fig. C10.	Workstation (3 panels)	Sponsored by GSA and performed at BFRL in 1991.	283	386	550	550	1142	6719.7	103	0.094260	0.019174

* BFRL – Building and Fire Research Laboratory
** GSA – General Services Administration

Figure H.7: Test results for Wooden Pallet (Building and Fire Research Laboratory)

H.5.6 Decay Phase – Forklift Fire

The decay phase for the forklift fire occurs following the steady state period. Utilising the test data presented above, the results show that the decay stage follows a parabolic nature for a period of time.

As the simulation of the design fire is for 2,700 seconds, the results show a considerable decrease from the peak heat release rate to the heat release rate at 2,700 seconds as all of the available fuel is consumed.

As a consequence and in order to add a layer of conservatism, the decay stage shall follow a sprinkler extinguishment relationship developed by NIST (1993) which has a longer decay phase when compared to the proposed vehicle fire.

$$\dot{Q}(t - t_{act}) = \dot{Q}(t_{act})\exp\left[\frac{-(t - t_{act})}{3.0(\dot{w}'')^{-1.85}}\right]$$

H.5.7 Decay Phase – Timber Storage Pallet Fire

The decay stage for the timber storage pallet fire occurs after the steady state period. Utilising the test data presented above and the heat release curve illustrated in the figure below, the results show that the decay stage follows a parabolic nature for a period of time. The results indicate that it takes approximately 1000 seconds prior to full extinguishment. In this instance, a similar rate of decay shall be considered however a linear relationship shall be adopted. This is a conservative approach as the parabolic relationship decays at a faster rate as opposed to the linear relationship.

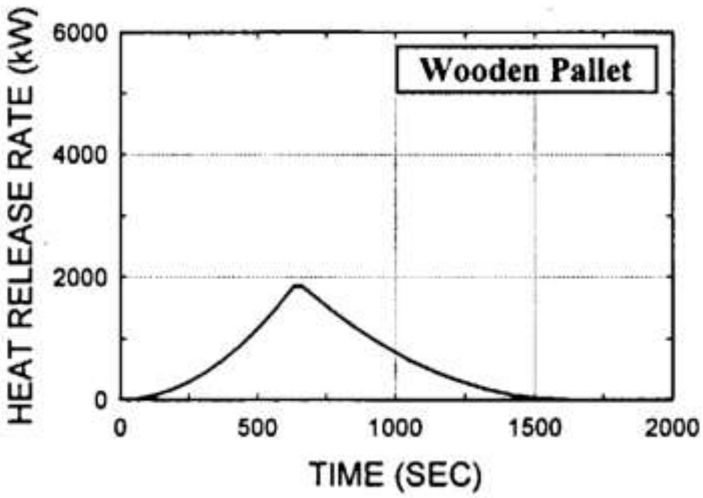


Figure H.8: Heat Release rate curve for Stack of Wooden Storage Pallets (Building and Fire Research Laboratory)

H.5.8 Fire Spread from Forklift to Timber Storage Pallet

In order to simulate fire spread from a forklift to a stack of wooden storage pallets, it is paramount to calculate the piloted ignition time for the stack of timber pallets. It should be noted that testing and literature reviews preformed and documented in codes around the world have concluded that timber is not readily ignited. There are a few recorded cases however where timber has been the first material to be ignited. Timber requires surface temperatures well in excess of 400°C if the material were to ignite in the medium to a short-term without the presence of a pilot flame. Even when a pilot flame is present, the surface temperature will need to be in the range of 270-300°C for a significant time before ignition occurs (et al Timber Structures). It was calculated via CFD modelling in a warehouse environment that the forklift fire produced temperatures of 300°C in approximately 375 seconds. To account for the timber storage pallets to undergo pyrolysis and combustion process, a further 100 seconds was added. Therefore, the time for fire spread to occur from a forklift fire to a stack of timber storage pallets is 475 seconds.

H.5.9 Design Fire

Utilising the information presented above the Heat Release Rate v Time Curve is presented in Figure H.9 for the overlapped forklift and storage pallet fire.

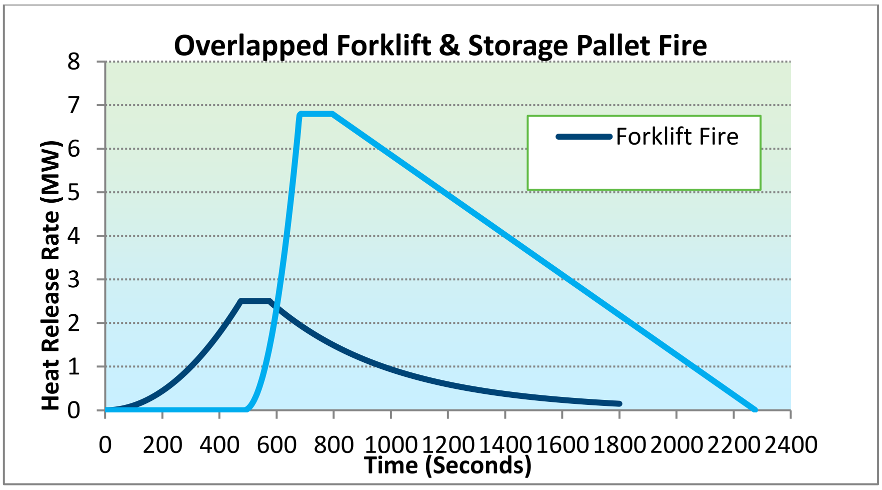


Figure H.9: Overlapped design fires for forklift and stack of wooden storage pallet

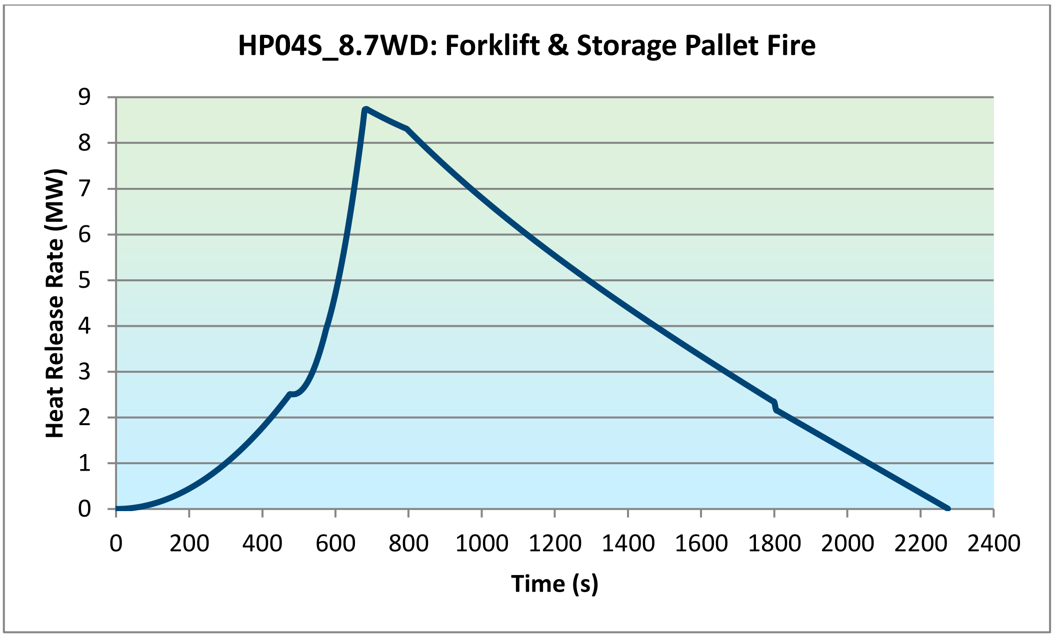


Figure H.10: HP04S_8.7WD Schematic design fire

Utilising the information presented above, the Heat Release Rate v Time Curve is presented in Figure H.10 for the resultant combined forklift and storage pallet fire.

The subject warehouse is expected to have numerous types of electrically powered forklifts, pallet lifts and the like operating throughout the building. Whilst it is unclear how many industrial fires are caused by forklift ignition sources and accidents, these fires are nonetheless well represented in the statistics and as such are considered relevant to the assessment for the subject premise. The lifting equipment shall be used to transport the commercial goods to and from the sortation section of the building and stored on pallets or within the racking system. In this instance, the sensitivity fire scenario has been developed whereby a forklift fire shall initiate before spreading to the sortation equipment where the pallets and additional storage materials may be located as part of the sortation process. Published research material, a degree of engineering judgement and assumptions have been adopted to quantify the time when fire from the forklift is likely to spread to potential storage pallets and other combustible materials.

Referring to Figure H.11 a standard medium t^2 fire growth rate and a fast t^2 fire growth rate have been superimposed over a custom fire which shall be adopted in this instance due to the unique frozen goods stored within the building.

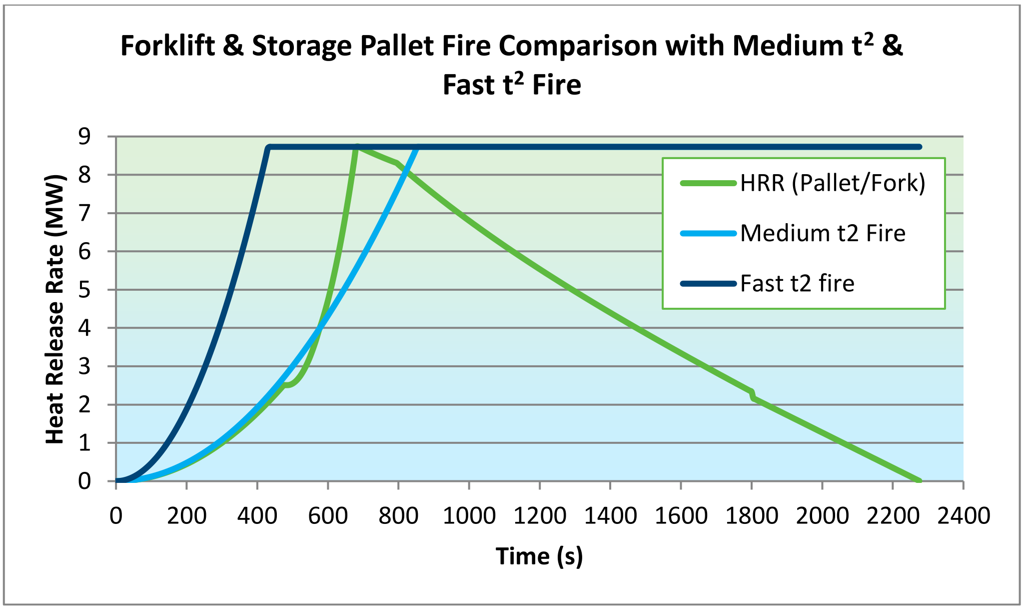


Figure H.11: Medium and fast t^2 Design Fire Growth Rates Comparison to the Custom Design Fire

H.5.10 Custom Design Fire Summary

A slower design fire curve may represent the initial stages of a fire. The purpose of a slower fire growth rate may be due to the initiating event being componentry within the forklift equipment having an incipient initial growth stage. The shielded nature of the forklift contributes to the fire growth rate. The fire eventually develops and spreads to the combustible pallet storage in close proximity. The storage/racking arrangement would be expected to be a combination of non-combustible metal and hard plastic, rubber materials and so on. The commodities being stored may not always be densely packaged whereby the fire is expected to be fuel controlled.

From a design perspective and in order to deviate from other sprinkler protected design fire scenarios already proposed as part of the overall assessment, a slightly slower growth rate fire scenario has been nominated in order to test the egress provisions and evacuation of the multitude of occupants within the warehouse. The non-sprinkler protected fire scenario will inevitably delay fire detection and notification, hence delaying the commencement of pre-movement and movement times. Occupants are most likely to rely on visual cues without the reliance on the automatic fire sprinkler system activating the BOWS. The scenario, in essence, is predominantly an ‘evacuation’ sensitivity scenario which considers maximum occupant numbers throughout the warehouse portion of the building.

A custom t^2 fire growth rate (which is appropriate to some of the credible fuel loads within this building) can be utilised which will (purposefully) generate initial lower temperatures during the growth phase of fire development coupled with the benefit of the automatic sprinkler system being ignored. Although the hot layer temperatures may not be a critical factor, occupants will be exposed to smoke conditions and visibility will be the tenability criteria most likely to be compromised.

Appendix I. Fire Brigade Intervention Model

I.1 General

The Fire Brigade Intervention Model (FBIM) is an event-based methodology which quantifies Fire Brigade activities from the point from Fire Brigade notification through to search, rescue, fire control and extinguishment and overhaul activities. In this instance, Fire Brigade tenability is proposed to be analysed and compared in terms of temperature and fire-fighter exposure limits, however Fire Brigade tenability is proposed to be analysed in terms of fire crew notification, intervention and fire control activity times for a response to the proposed building.

The Fire Brigade Intervention has been assessed whereby Fire Brigade Intervention and/or fire-fighting operations are listed as sub-requirements of the relevant Performance Requirements of the BCA. For the purpose of determining a time at which the local fire brigade would attend the subject building (i.e. kerb side) and apply water, a Fire Brigade Intervention Model (FBIM) (AFAC, 2020) has been undertaken. In the context of the design issues raised by the Principal Certifying Authority and identified within this report the fire services intervention activities are considered to be relevant to life safety of the occupants and rationalisation of the smoke hazard management system.

The nearest primary responding fire stations to the subject site via road travel have been illustrated in Figure I.1. The relevant fire stations are as follows:

- Huntingwood Fire Station located at 42 Huntingwood Dr, Huntingwood, NSW (approximately 9.1km away); and
- Bonnyrigg Heights Fire Station located at 70 Gloucester St, Bonnyrigg Heights, NSW (approximately 14.6km away).

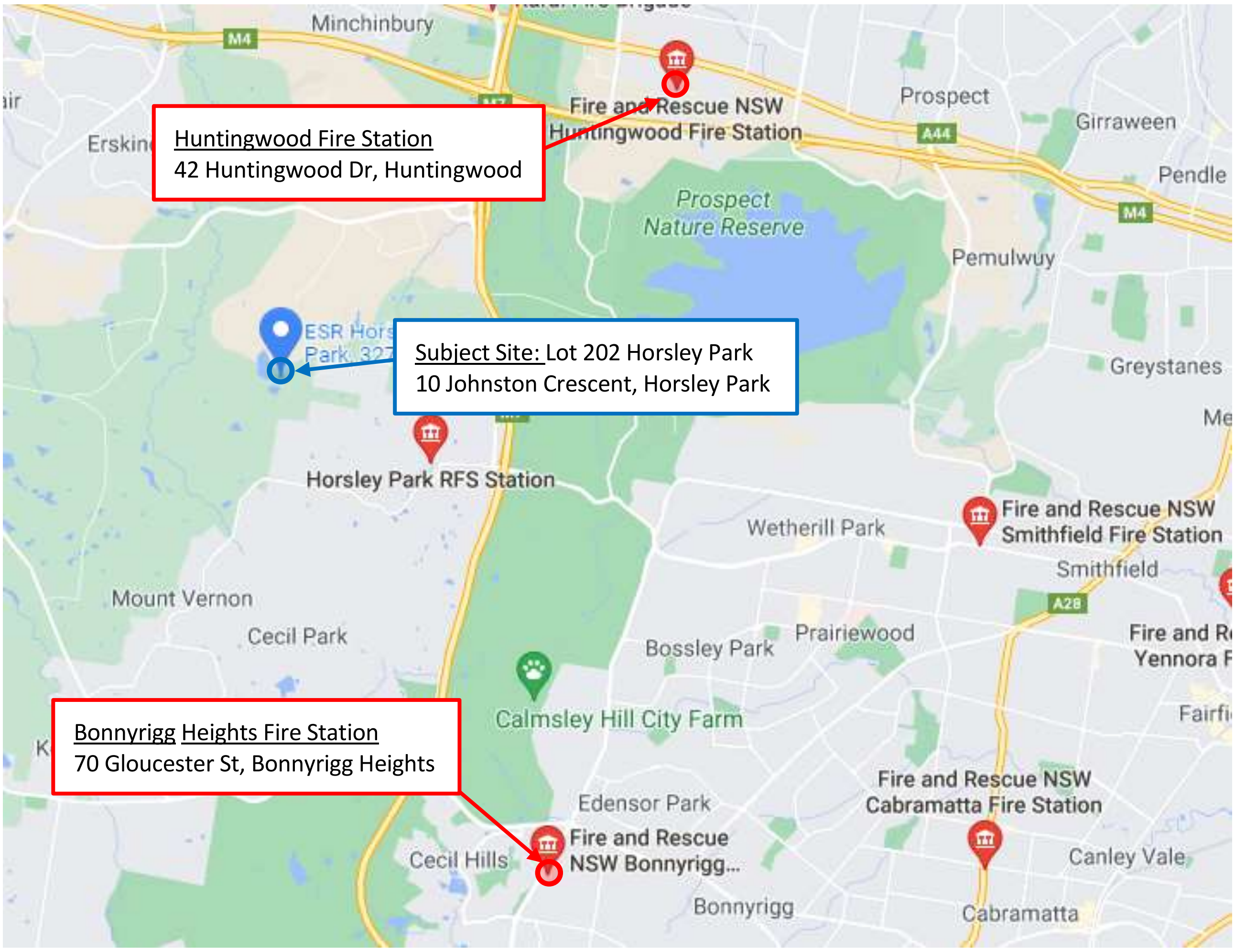


Figure I.1: Primary responding FRNSW fire stations (Huntingwood & Bonnyrigg Heights) to 202 Horsley Park

I.2 Assumptions and Parameters

In this instance, a FBIM was undertaken from notification to commencement of water application at the most remote location of the building. The following assumptions and parameters were also adopted to determine Fire Brigade Intervention:

- Google Maps TM has been used to identify the most appropriate travel time from the station to the subject site.
- Based on information provided by FRNSW, both the nominated fire stations are permanently staffed;
  - As the fire stations are fully manned, the FBIM timeline has adopted an additional 90 seconds to account for firefighter response with respect to "Time to dress, assimilate information and depart";
- Fire fighters including the Officer in Charge (OIC) would be required time to don BA gear and gather necessary information.
- Detection is based on Sprinkler activation
  - The sprinkler activation times were determined using Alpert's Correlation. The spread sheet model has computed the thermal response of a sprinkler head located near the roof. The formulas are calculated with reference to R.L. Alpert Fire Technology 1972 pp181-195.
  - The activation of the automatic fire sprinkler system is expected to occur at 218 seconds.
  - The sprinkler activation time is based on Fire Scenario HP01C_8.6WA
- Assume fire-fighters travel to the subject site and set up in the most practical area for the fire brigade appliances. The fire brigade are assumed to set up at the main entrance location in front of the building to assess the location of the fire.
- The attending crew would be expected to receive information about the location of the fire via the main Fire Indicator Panel (FIP) if it was not visible upon arrival.
- As the occupants are expected to be evacuated and/or in the process of evacuation from the building forced entry is not expected.
- Fire crews deploying Standard Operational Guidelines (SOG's) and equipped with fire-fighting tools and protective clothing are unlikely to be at exposed to excessive fuel loads, ignition sources and extra ordinary hazards within the subject building when compared to a building solution compliant with the DtS provisions of the BCA.

I.2.1 Time to Reach Fire Scene

The nearest fire stations to the subject site are Huntingwood and Bonnyrigg Heights Fire Station. The anticipated primary response is detailed in Table I.1.

Table I.1: FRNSW Fire Brigade – Primary Responding Stations

Fire Station	Address	Distance
Huntingwood Fire Station	42 Huntingwood Dr, Huntingwood, NSW	9.1km
Bonnyrigg Heights Fire Station	70 Gloucester St, Bonnyrigg Heights, NSW	14.6km

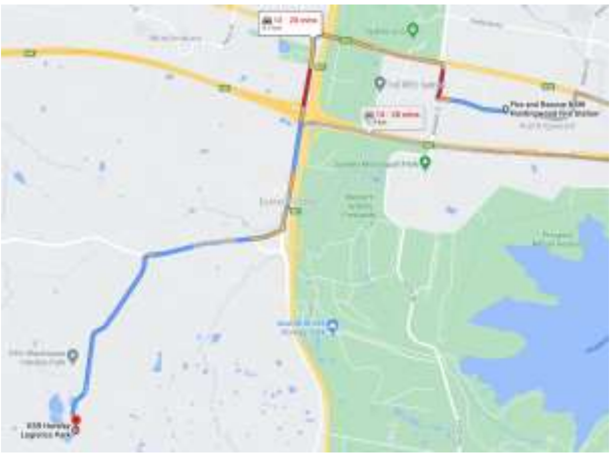
The time taken for fire crews to reach the scene has been based upon a number of digital mapping scenarios utilising Google Maps TM. In order to achieve the most appropriate approach and in line with the AFAC FBIM Model Manual (Version 3.0, dated 14/04/2020) the analysis has adopted the following:

- Times have been collected from both the closest and second closest fire stations. The time adopted has been based on the second closest station to allow the possibility that the appliance(s) closest may already be in use.
- Sample times have been considered for different days of the week and at different times.
- The travel time adopted is representative of the median taken from the slowest time sample.

Table I.2 & Table I.3 provide a summary of the digital mapping scenario outcomes for the subject building and responding fire stations.

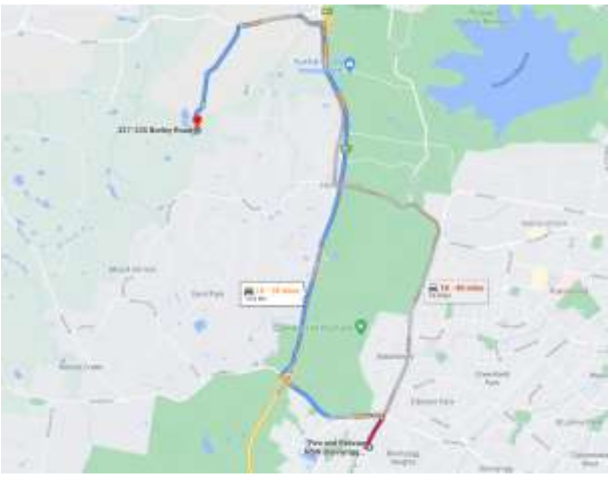
Table I.2: Closest appliance travel times using digital mapping (Huntingwood Fire station)

Responding Fire Station	Mapping Snapshot	Distance	Day of the Week	Time of Day	Time Range
Huntingwood Fire Station		9.1km	Tuesday	08:30	10-26 min
				12:00	10-26 min
				17:00	12-28 min
				23:00	10-16 min
			Friday	08:30	10-24 min

Responding Fire Station	Mapping Snapshot	Distance	Day of the Week	Time of Day	Time Range
				12:00	10-24 min
				17:00	12-28 min
				23:00	10-16 min
			Saturday	08:30	10-18 min
				12:00	10-20 min
				17:00	10-16 min
				23:00	10-14 min

**Red indicates the longest estimated arrival time*

Table I.3: Second closest appliance travel times using digital mapping (Bonnyrigg Heights Fire station)

Responding Fire Station	Mapping Snapshot	Distance	Day of the Week	Time of Day	Time Range
Bonnyrigg Heights Fire Station		14.6km	Tuesday	08:30	16-30 min
				12:00	14-24 min
				17:00	16-30 min
				23:00	14-18 min
			Friday	08:30	14-28 min
				12:00	14-24 min
				17:00	16-26 min
				23:00	14-18 min
			Saturday	08:30	14-20 min
				12:00	14-22 min
				17:00	14-20 min
				23:00	14-18 min

**Red indicates the longest estimated arrival time*

From the mapping scenarios collected the longest of the median arrival times are as follows:

- Huntingwood Fire Station: 20 minute or 1200 seconds (closest)
- Schofields Fire Station: 23 minutes or 1380 seconds (second closest)

I.2.2 Fire-fighter travel

I.2.2.1 Fire-fighter Horizontal Travel

Upon fire incident call-out, FRNSW will arrive kerbside along via the access road on Johnston Crescent. The attending fire crews will be required to travel (on foot) to the FIP which shall be located near/adjacent the main entrance. The following steps portray the assumed path of travel nominated for the FBIM scenario for fire-fighting operational procedures with a fire origin occurring within the development (refer to Figure I.2):

- Fire-fighters arrive onsite whereby the Office in Charge (OIC) proceed to the FIP (within the main entrance) to confirm the fire location. The OIC will then conduct a perimeter walk of the fire affected area from the set-up area;
- Fire crews will don BA equipment, gather necessary tools and proceed to the nearest available fire hydrant outlet from where they connect and charge their hydrant hose lines;
- Fire-fighters proceed to the area of fire origin with a charged hose line ready to perform fire extinguishment operations.

Table I.4: Fire-fighter horizontal travel speed (Table Q, AFAC 2020)

Graph	Travel Conditions	Speed (m/s)	
		μ	σ
Q1	Dressed in turnout uniform	2.3	1.4
Q2	Dressed in turnout uniform with equipment	1.9	1.3
Q3	Dressed in turnout uniform in BA with or without equipment	1.4	0.6
Q4	Dressed in full hazardous incident suit in BA	0.8	0.5

Horizontal travel time is based upon the data provided in the AFAC dataset (Version 2020.05, dated May 2020). In this instance fire crews are considered to arrive dressed in turnout uniform with BA & equipment.

Based on a research paper "Speed Distribution Curves for Pedestrians during Walking and Crossing" (Chandra et. al, 2013), the pedestrian walking speed was normalised based on data collected throughout 2008 to 2009. The research was conducted in India and seven (7) sites were selected for the study, four for walking and three for crossing conditions. The details of study locations are shown in Figure I.2.

Sl. No.	Location	Type of Facility	Pedestrian Movement	Sample Size
1	Outside railway station, Coimbatore	Sidewalk	Walking	239
2	Outside income tax office (I.T.O.), New Delhi	Wide-sidewalk	Walking	234
3	City centre, Chandigarh	Precinct	Walking	168
4	Gandhipuram, Coimbatore	Carriageway	Walking	379
5	Connaught place, New Delhi	2-lane, Unidirectional	Crossing	281
6	Sukna lake, Chandigarh	3-lane undivided, Bi-directional	Crossing	47
7	Old Washermenpet, Chennai	4-lane undivided,	Crossing	175

Figure I.2: Details of study location

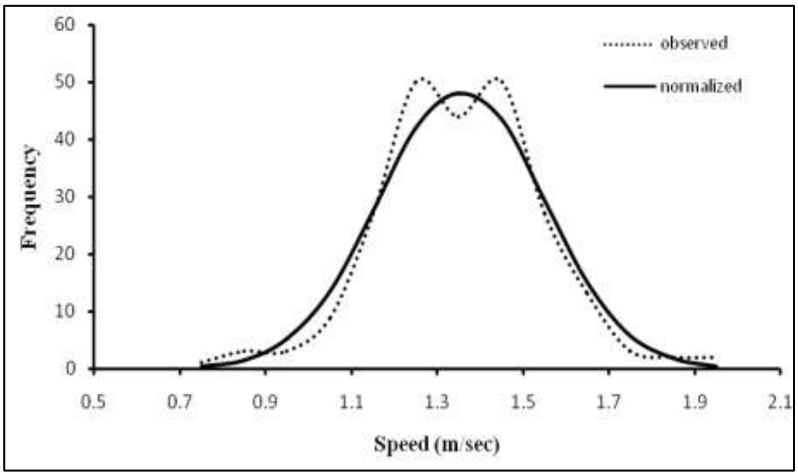


Figure I.3: Normalised distribution of pedestrian walking speed

As shown in Figure I.3, a normalised distribution was fitted into the data. With respect to the FBIM, as the normal distribution is justified, a k-factor of 0.67 shall be adopted (based on FBIM V2.2 October 2004- Section 4).

Applying a 75th %-ile k-factor of 0.67 (Table 4.3 of FBIM V2.2 October 2004- Section 4), mean (μ) of 1.4m/s and a standard deviation (σ) of 0.6m/s (refer to Table I.4), the horizontal travel speed is calculated as follows to accommodate that operational firefighters are expected be moving faster than average speed recorded in experimental trials:

s = μ + (k × σ) (AFAC FBIM Model Manual, 2020)

s = 1.4 + (0.67 × 0.6)

s = 1.8 m/s

I.2.2.2 Fire fighter Travel Path

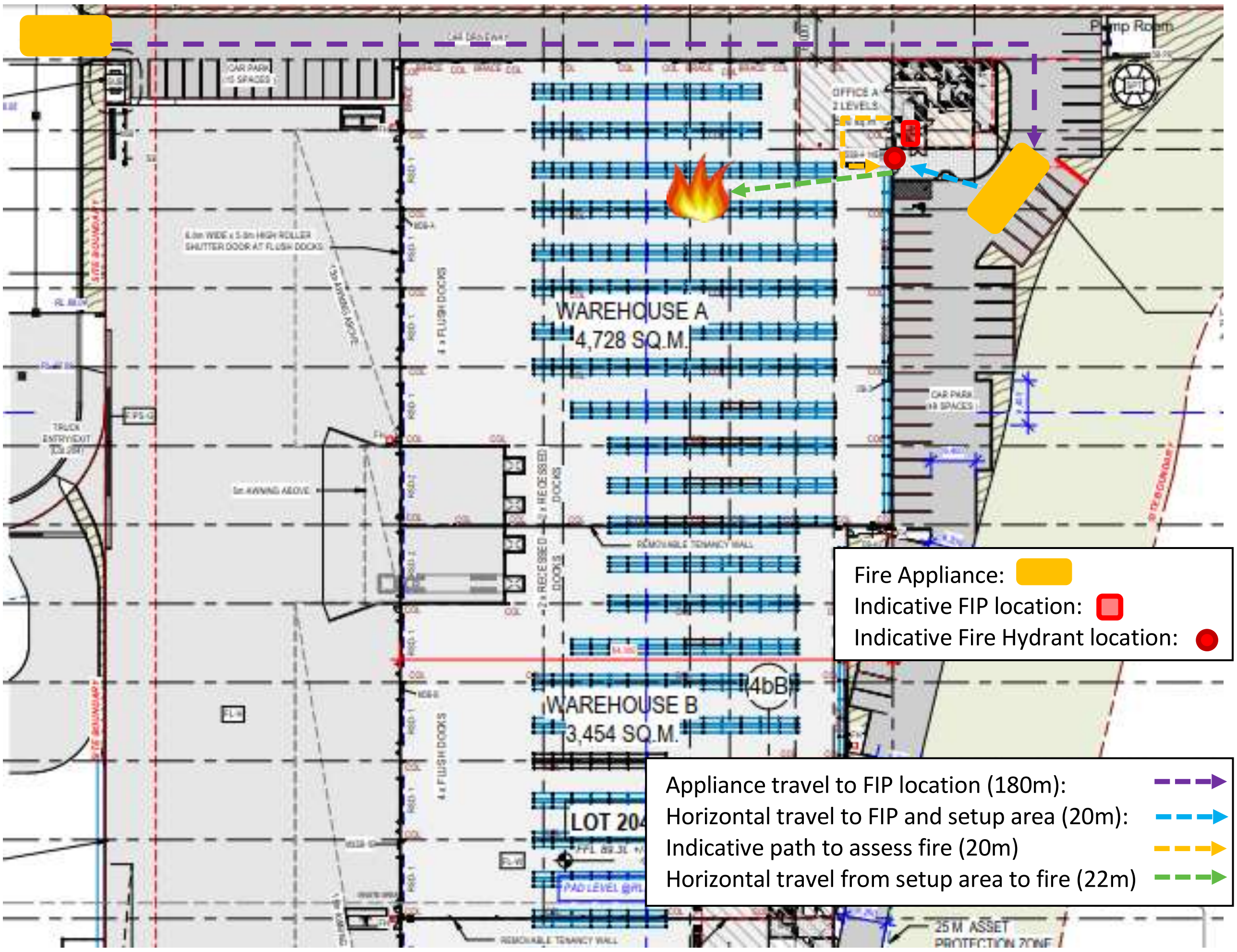


Figure I.4: Travel through site from FIP

I.3 Time for Fire Brigade Intervention

The activities performed by the attending fire crews, the time associated per activity and the cumulative time from fire initiation until the commencement of water application onto the fire is tabulated below.

Table I.5: Fire Brigade Intervention Model Timeline

Activity	Time Per Activity	Cumulative Time	FBIM Details
Time for fire detection (sprinkler activation)	218	218	Refer to Section 6.
Time to depressurise system and activate alarm	180	398	Table A, Chart 1
Time delay for alarm verification	20	418	Table B, Chart 1
Time for fire-fighter response	90	508	Time to dress, assimilate information and depart Table E, Chart 3
Time to reach fire scene (kerb side)	1200	1708	Travel time for closest fire appliance (Huntingwood Fire Station), refer to Table I.2 for digital mapping analysis outcomes, Chart 4
	1380	1888	Travel time for second closest fire appliance (Bonnyrigg Heights Fire Station), refer to Table I.3 for digital mapping analysis outcomes, Chart 4
Time for travel through site to FIP	81	1969	Time to move fire appliance (180m at 8km/hr), Table F, Chart 8
Time to dismount fire appliance and don BA	158	2127	Dismount appliance and don BA (75^{th} %ile k=2, μ = 88.1 & σ = 34.9), s = 88.1+(2x34.9) = 158 sec, Table M, Chart 6

Activity	Time Per Activity	Cumulative Time	FBIM Details
Time for horizontal fire-fighter travel to FIP	11	2138	Time for OIC to walk to FIP, s=20m/1.8ms^{-1} =11seconds, Table Q, Charts 5 & 9
Time for information gathering	90	2228	Time for fire location confirmation at FIP, building floor area >10000, Table L, Chart 5
Time to remove necessary tools from appliance	69	2297	Hydrant Equipment (75th %ile k=2, μ = 32.5 & σ = 18.1), s = 32.5+(2x18.1) = 69 sec, Table P, Chart 6
Time to assess fire	11	2308	Time for OIC to walk around fire area and return, 20/1.8ms^{-1}=11, Table Q, T, Chart 7
Time to conduct safety procedures	74	2382	Time to flush hydrant, (75th percentile k=2, μ = 32.8 & σ = 20.6), s = 32.8+(2x20.6) = 74 sec, Table O, Chart 6
Time to connect and charge hoses to booster hydrant	135	2517	Time to lay, connect and charge hose. Connect 65mm hose to booster hydrant and charge (75th %ile k=2, μ = 59.6& σ = 37.9, s = 59.6 + (2x37.9) = 135 sec Table V, Chart 10
Time for fire-fighter travel from set-up area to fire zone	12	2529	Time for fire crews to travel to fire zone, s=22/1.8ms^{-1}=12sec, Table Q, Charts 9 & 10
Total FBIM time from fire initiation to commence water control and/or extinguishment activities	-	2349	Travel time for closest fire appliance (Huntingwood Fire Station)
	-	**2529**	Travel time for second closest fire appliance (Bonnyrigg Heights Fire Station)

Referring to Table I.5 above the approximate times for the closest & second closest fire stations, Huntingwood and Bonnyrigg Heights Fire Stations has been provided. The FBIM timeline indicates the following:

- From fire initiation the cumulative time taken for the closest & second closest fire appliances to reach the fire scene (kerb side) are as follows:
  - Closest (Huntingwood Fire Station): **1708 seconds** or approximately 28.5 minutes;
  - Second Closest (Bonnyrigg Heights Fire Station): **1888 seconds** or approximately 31.5 minutes;
- Having arrived at the fire scene (kerb side), the cumulative time taken for fire crews to gain entry, gather information, assess the situation and set-up water supplies ready for the commencement of water control/extinguishment activities is an additional **641 seconds** or approximately 10.5 minutes;
- From fire initiation to the commencement of water control/extinguishment activities the cumulative time take for the closest & second closest responding fire stations is as follows:
  - Closest (Huntingwood Fire Station): **2349 seconds** or approximately 39 minutes;
  - Second Closest (Bonnyrigg Heights Fire Station): **2529 seconds** or approximately 42 minutes

In line with the AFAC FBIM Model Manuel (Version 3.0, dated 14/04/2020) the total time taken for fire brigade intervention is based upon the second closest fire station. In this regard, attending fire crews from Bonnyrigg Heights Fire Station are expected to conduct water control/extinguishment activities within **2529 seconds** or approximately 42 minutes.

Appendix J. FRNSW Response to FEBQ

Parkan Behayeddin

From:	Fire Safety <FireSafety@fire.nsw.gov.au>
Sent:	Tuesday, 10 August 2021 10:16 AM
To:	Kenny Leong
Cc:	'Hong Lau'; Eng Tan; Owen Bersenev; Metin Tokcan; gpearce@mckenzie-group.com.au; PCassimatis@hansenyuncken.com.au; Parkan Behayeddin
Subject:	FEBQ will not be provided - 204 Horsley Park, Logistics Park (10 Johnston Crescent, Horsley park NSW) - [EMAIL 1 OF 3]

Good Morning Kenny,

Fire & Rescue NSW (FRNSW) acknowledge receipt of your application and supporting documents for a Fire Engineering Brief Questionnaire.

In this instance, FRNSW advises that an Fire Engineering Brief Questionnaire will not be provided.

The decision not to assess the Version (insert V3/V5 if necessary) submitted is not to be interpreted as FRNSW support for the proposal nor an objection to the proposal, only that FRNSW does not have the resources to review and provide stakeholder comment on this proposal.

For any future correspondence regarding this matter, we request that you quote your job / reference number:

Project Reference:	FRN20/887-1
Job Number:	BFS21/1563
SRID Number:	8000015567

Should you have any further queries regarding this matter, please contact the Fire Safety Branch on 02 9742 7434.

Regards

FIRE + RESCUE

Administration Officer
FIRE SAFETY ADMINISTRATION UNIT
COMMUNITY SAFETY DIRECTORATE

T: 02 9742 7434
E: firesafety@fire.nsw.gov.au
1 Amarina Ave, Greenacre, NSW 2190
Locked Mail Bag 12, Greenacre, NSW 2190
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Appendix K. Relevant Extracts from AS2419:2017

3.5.5 Protection of fire hydrants

3.5.5.1 *Non-sprinkler-protected buildings*

Where an external fire hydrant is located within 10 m of a non-sprinkler-protected building, it shall be protected as follows:

(a) If located within, or affixed to, the external wall of a building, by walls, floors and/or ceilings, as applicable, that—

(i) has an FRL of not less than 90/90/90;

(ii) extends for a distance of not less than 2 m each side of the centre-line of the fire hydrant riser; and

(iii) extends to a height of not less than 3 m above ground level.

(b) If located within 3.5 m of the external wall and remote from the building, by—

(i) the external wall of the building that—

(A) has an FRL of not less than 90/90/90;

(B) extends to a distance of not less than 2 m each side of the centre-line of the fire hydrant riser; and

(C) extends to a height of not less than 3 m above ground level;

or

(ii) a freestanding wall or similar construction that—

(A) has an FRL of not less than 90/90/90;

(B) extends to a distance of not less than 2 m each side of the centre-line of the fire hydrant riser;

(C) extends to a height of not less than 3 m above ground level; and

(D) is located immediately behind the fire hydrant and between the building and the fire hydrant.

(c) If located more than 3.5 m and not more than 10 m of the external wall of the building, by a freestanding wall or similar construction that—

(i) has an FRL of not less than 90/90/90;

(ii) extends for a distance of not less than 1 m each side of the centre-line of the fire hydrant riser, provided a minimum width of 3 m is achieved;

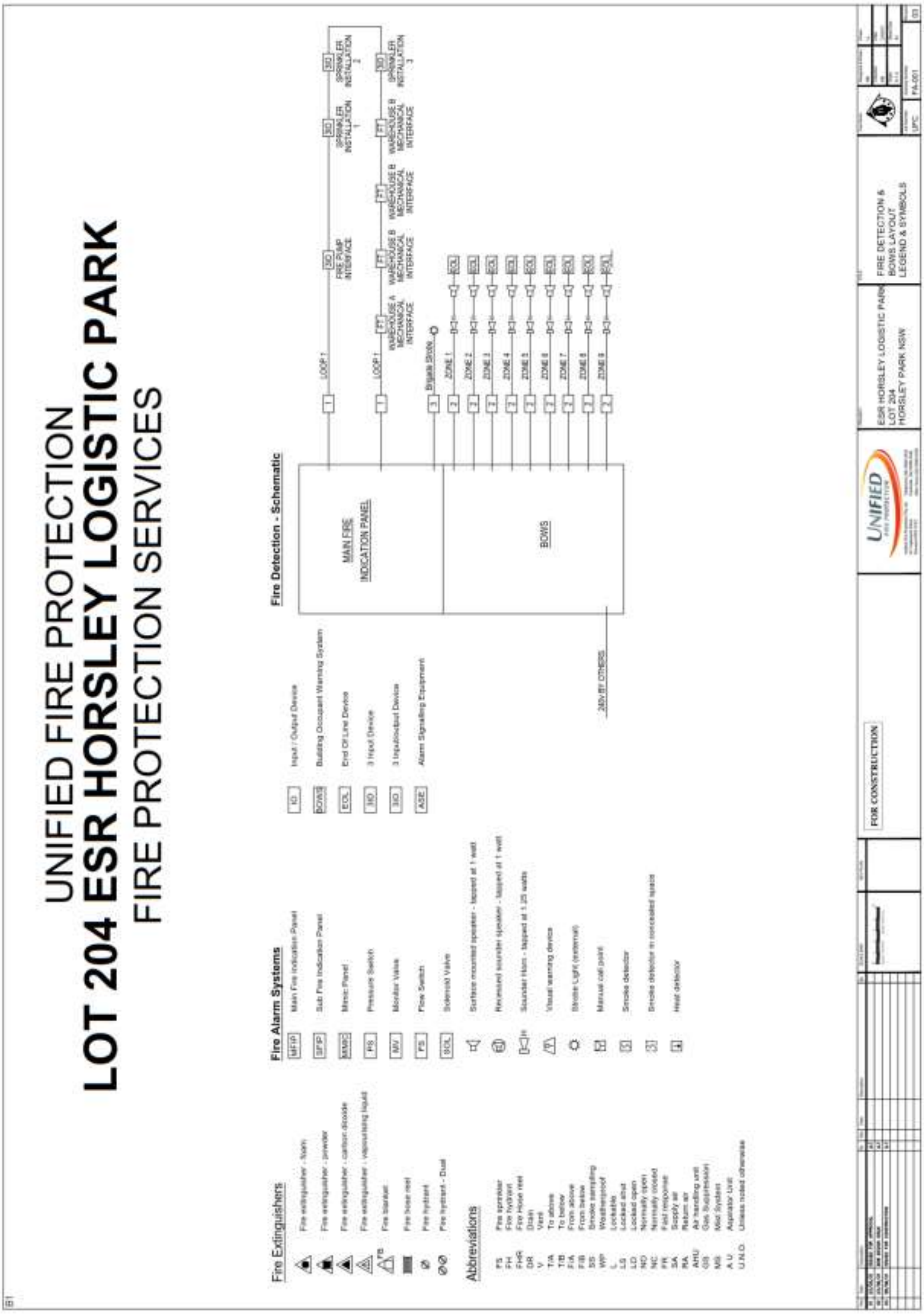
(iii) extends for a height of not less than 2 m above ground level; and

(iv) is located immediately behind the fire hydrant and between the building and the fire hydrant.

3.5.5.2 *Sprinkler-protected buildings*

Where a sprinkler system is installed throughout a building in accordance with the requirements of AS 2118.1, AS 2118.4 or AS 2118.6, the external fire hydrant(s) located within 10 m of the building need not be protected in accordance with the requirements of Clause 3.5.5.1.

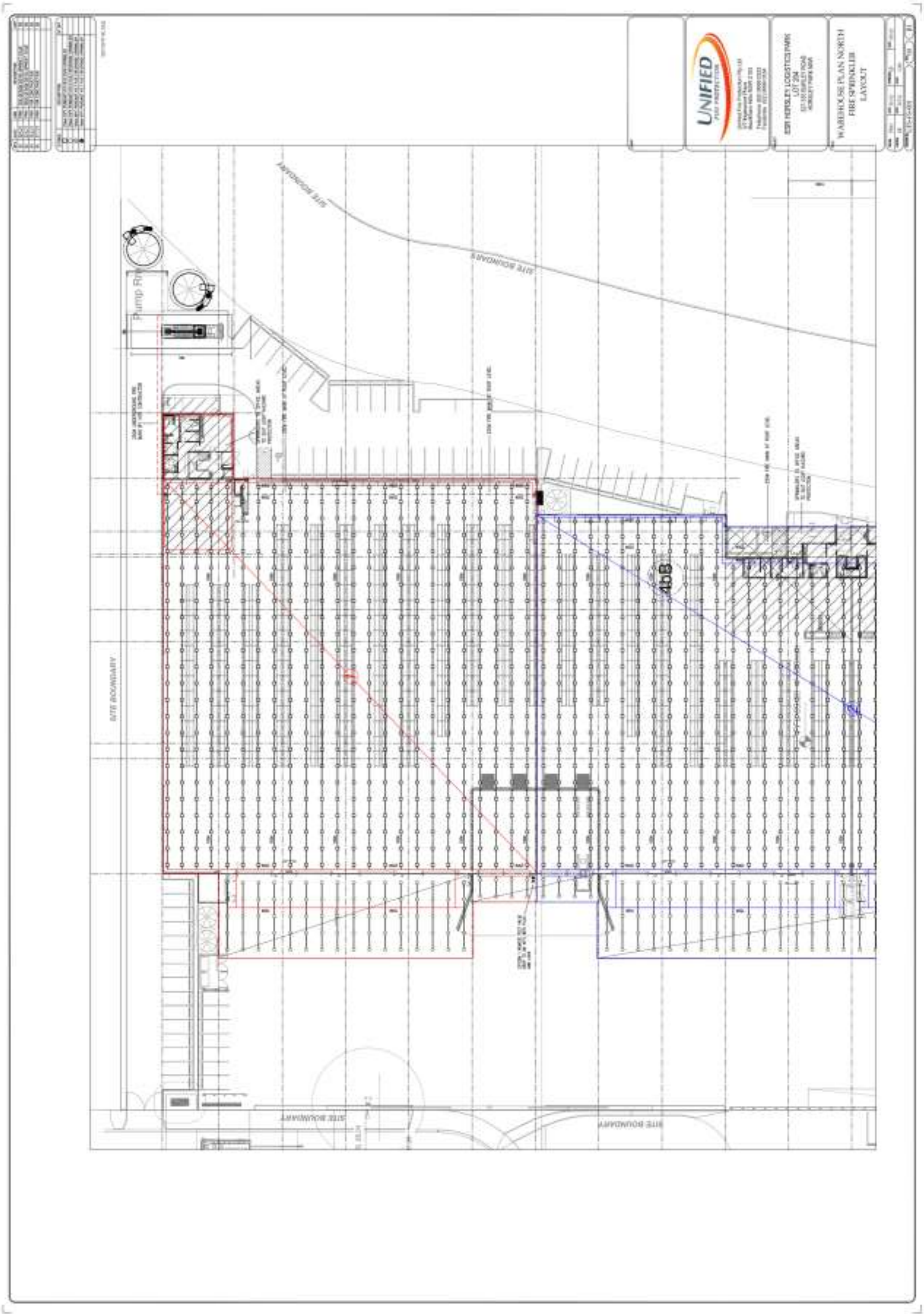
Appendix L. Fire Detection and Sprinkler Drawings



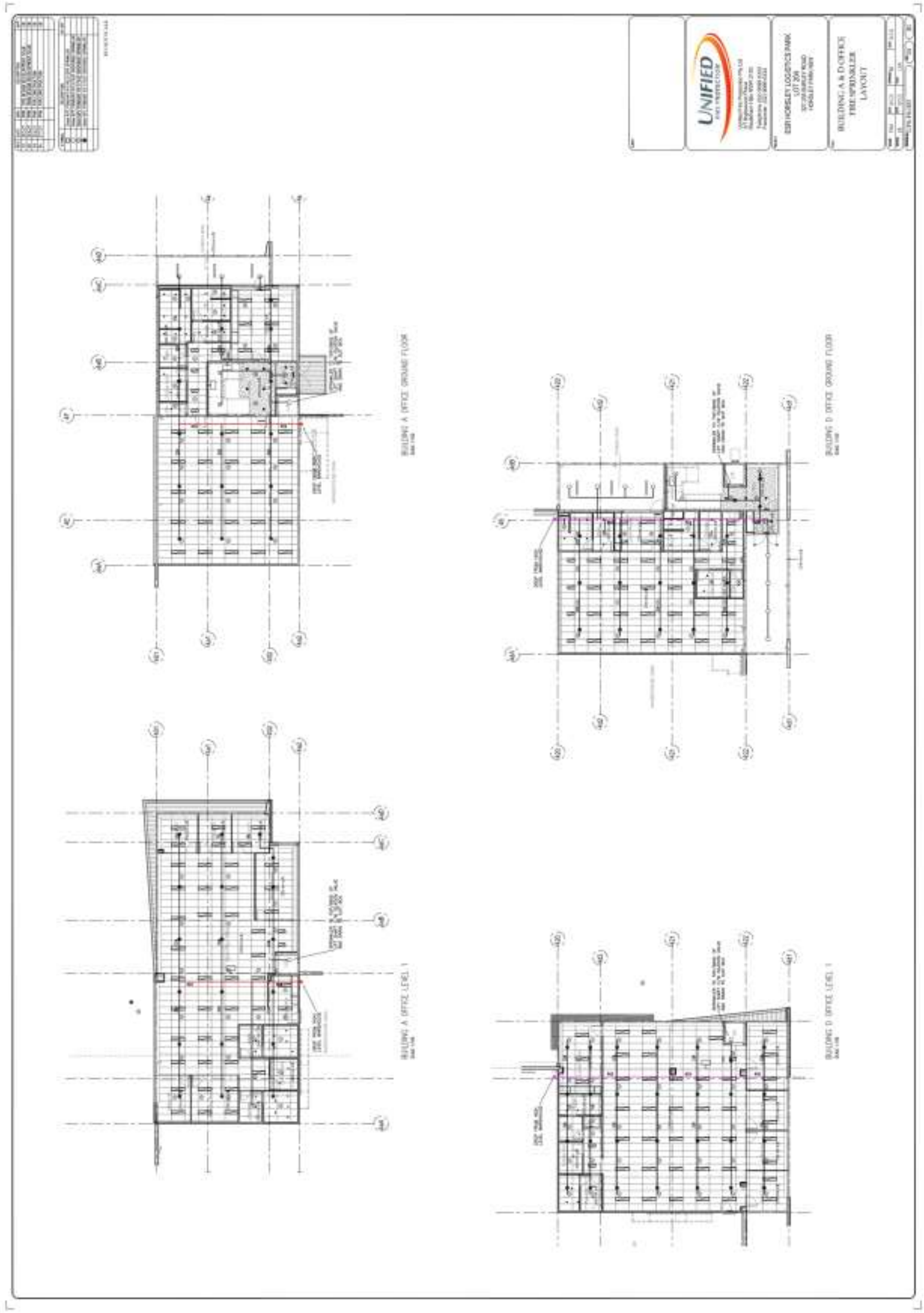

FIRE DETECTION &
BOWS LAYOUT
WAREHOUSE
ESR HORSLEY LOGISTIC PARK
LOT 204
HORSLEY PARK NSW
FOR CONSTRUCTION
UNIFIED
FA-002
ACCESS ROAD
LOT 201

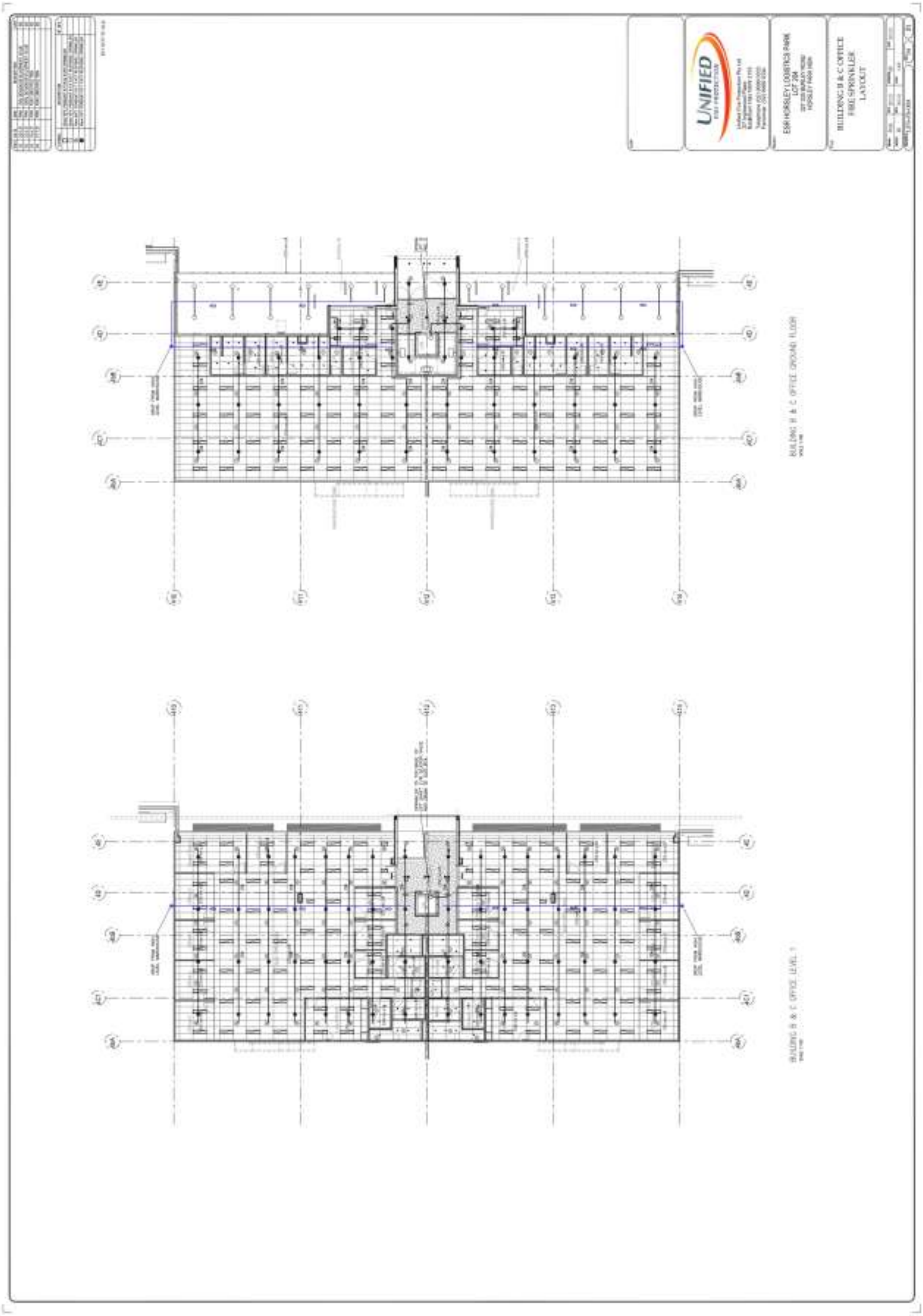

ZONE 09
MIMIC
Office Ground Floor (WH 204D)
ZONE 09
Office First Floor (WH 204D)
MFIP
BOWS
ZONE 01
Office Ground Floor (WH 204A)
ZONE 01
Office First Floor (WH 204A)
FOR CONSTRUCTION
UNIFIED
ESR HORSLEY LOGISTIC PARK
LOT 204
HORSLEY PARK NSW
FIRE DETECTION &
BOWS LAYOUT
OFFICE A & OFFICE D
UFC
FA-003

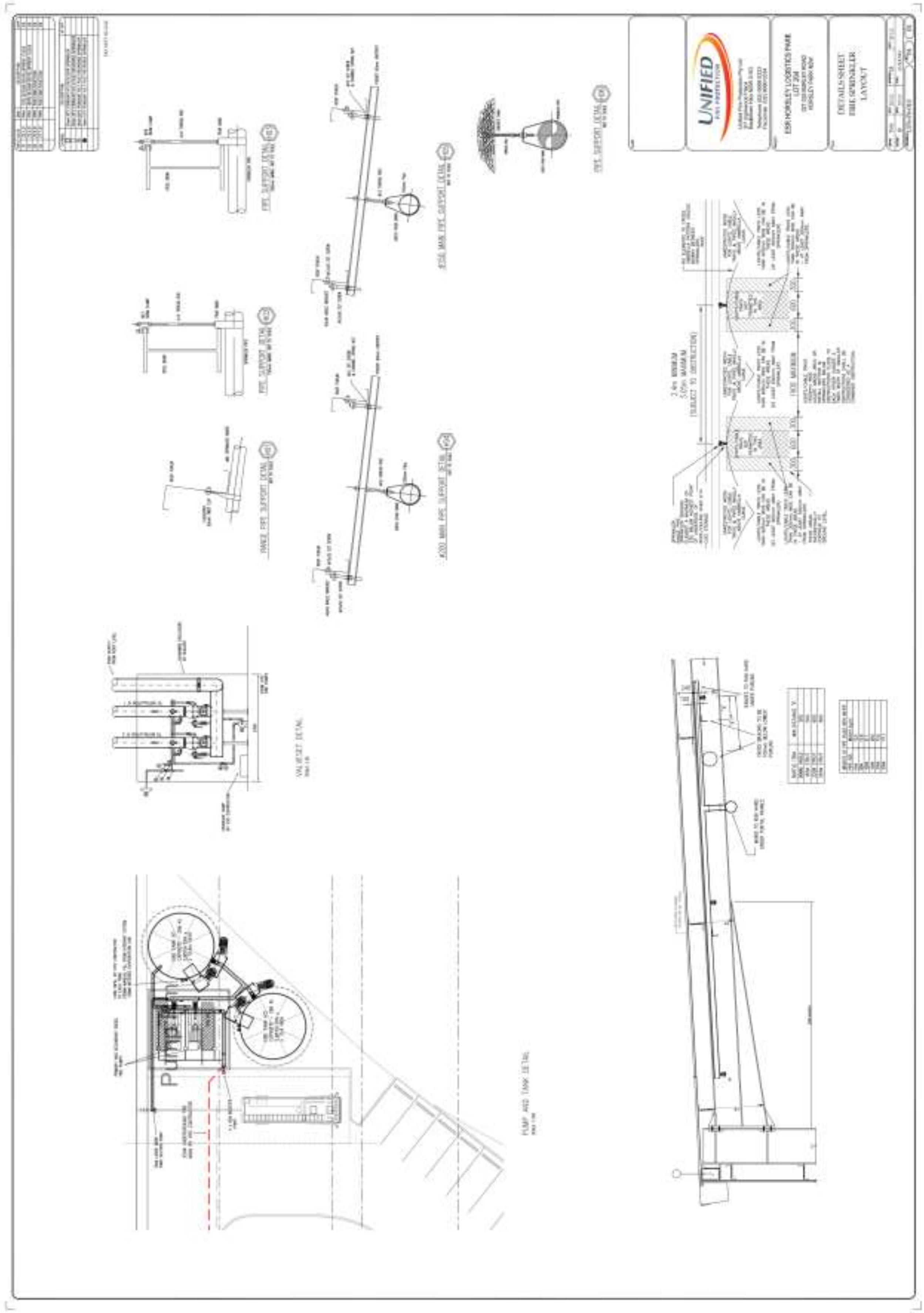

ZONE 05
ZONE 06
ZONE 05
ZONE 06
Office Ground First Floor (WH 204 B & C)
Office Ground Floor (WH 204 B & C)
FOR CONSTRUCTION
UNIFIED
FIRE DETECTION & BOWS LAYOUT OFFICE B & OFFICE C
ESR HORSLEY LOGISTIC PARK LOT 204 HORSLEY PARK NSW
UFC
FA-006
03


UNIFIED
ESR HORSLEY LOGISTICS PARK
LOT 204
WAREHOUSE PLAN NORTH
FIRE SPRINKLER
LAYOUT
SITE BOUNDARY
Pump Rm
4bB

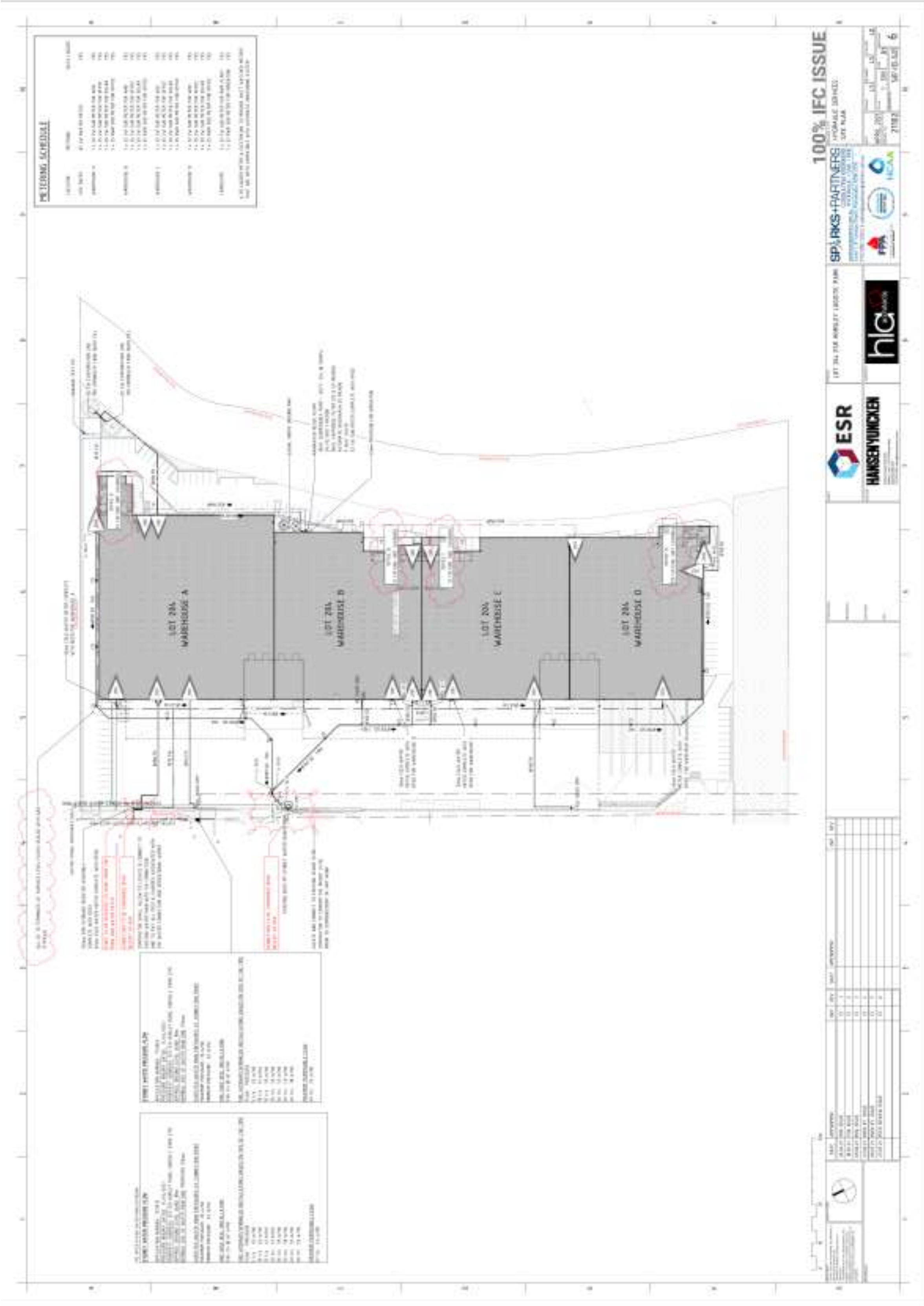

WAREHOUSE PLAN SOUTH
FIRE SPRINKLER
LAYOUT
SITE BOUNDARY

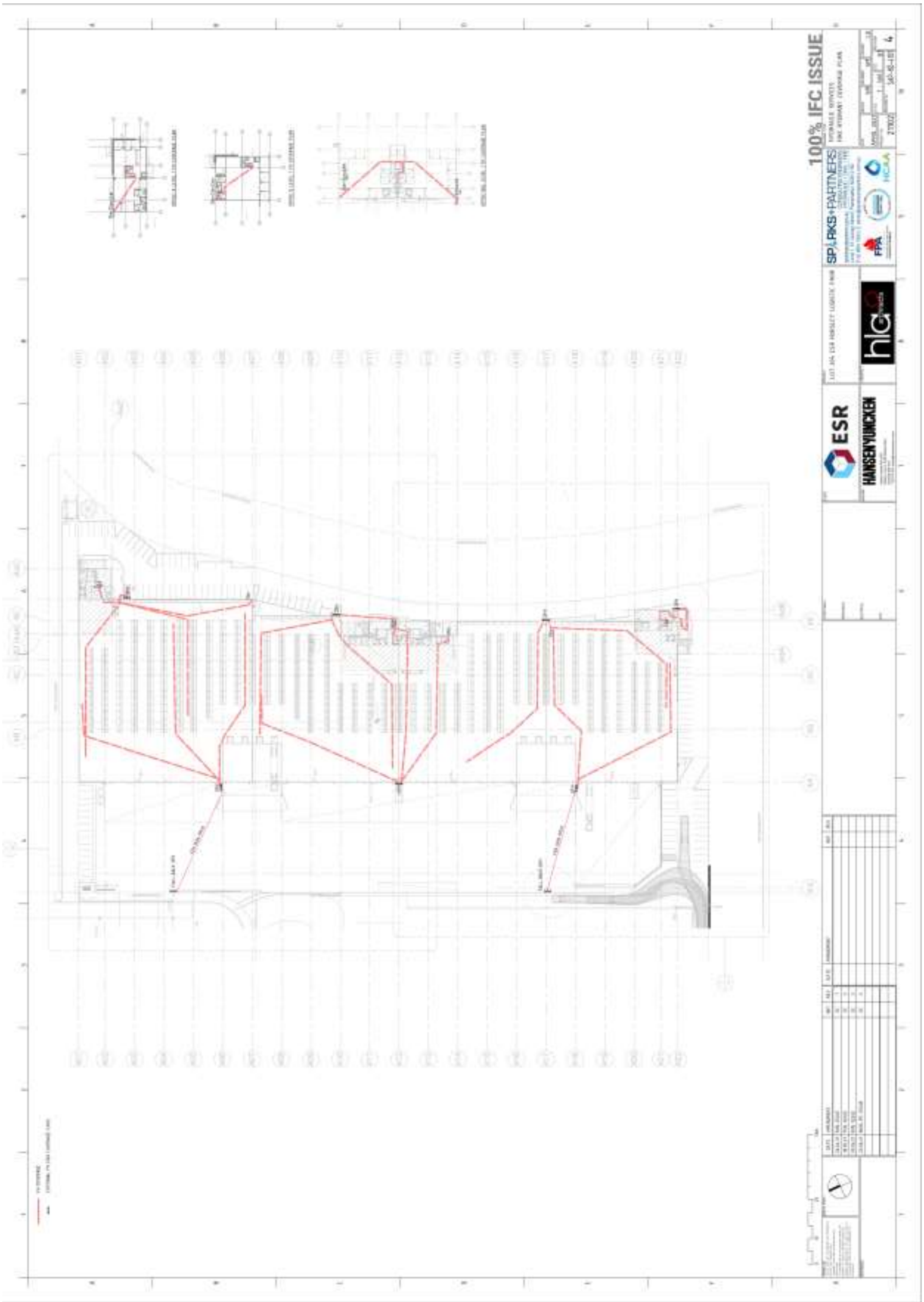

UNIFIED
BUILDING A & D OFFICE FIRE SPRINKLER LAYOUT
BUILDING A OFFICE GROUND FLOOR
BUILDING D OFFICE GROUND FLOOR
BUILDING A OFFICE LEVEL 1
BUILDING D OFFICE LEVEL 1

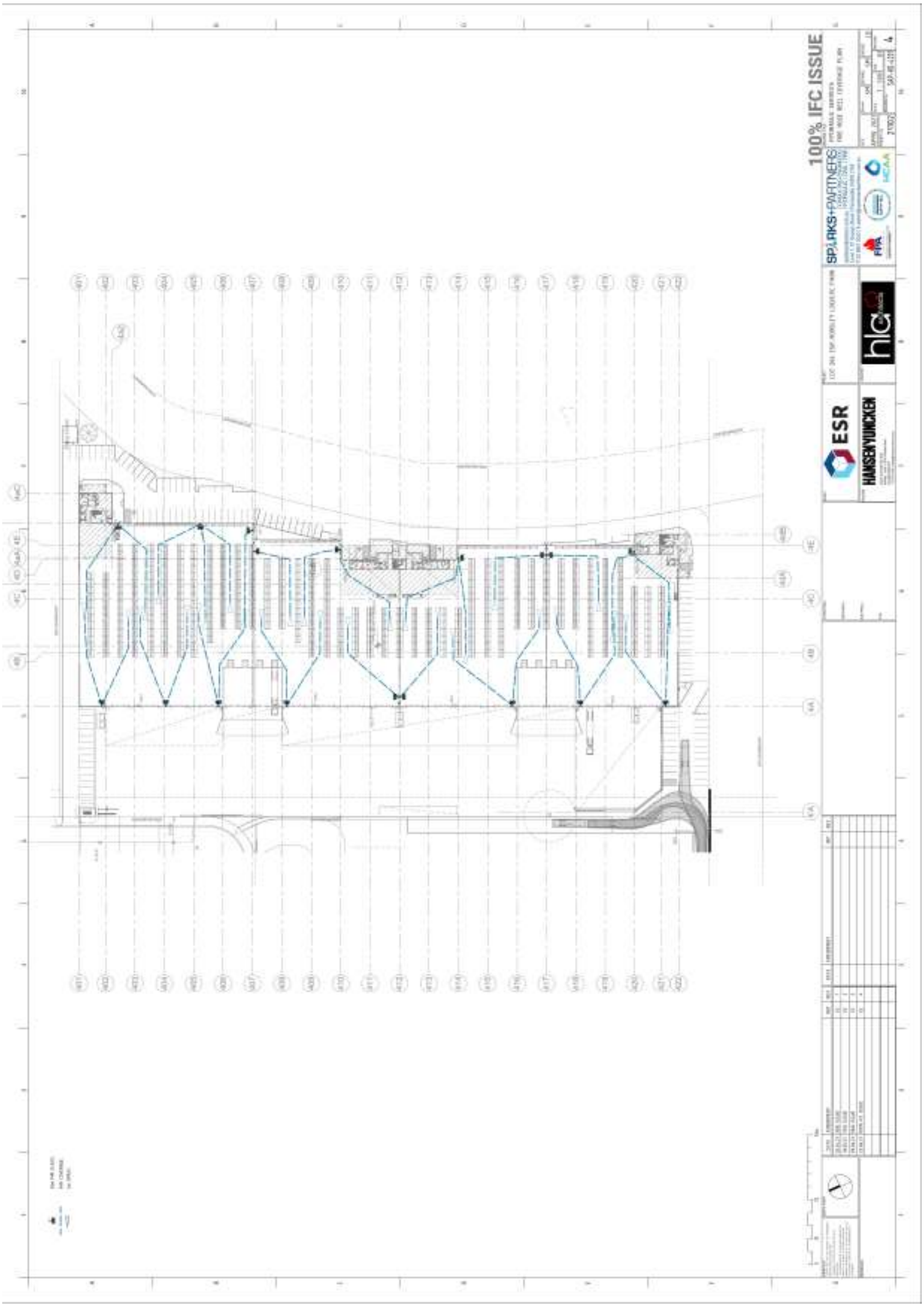



UNIFIED
VALVESET DETAIL
PUMP AND TANK DETAIL
DETAILS SHEET
FIRE SPRINKLER
LAYOUT

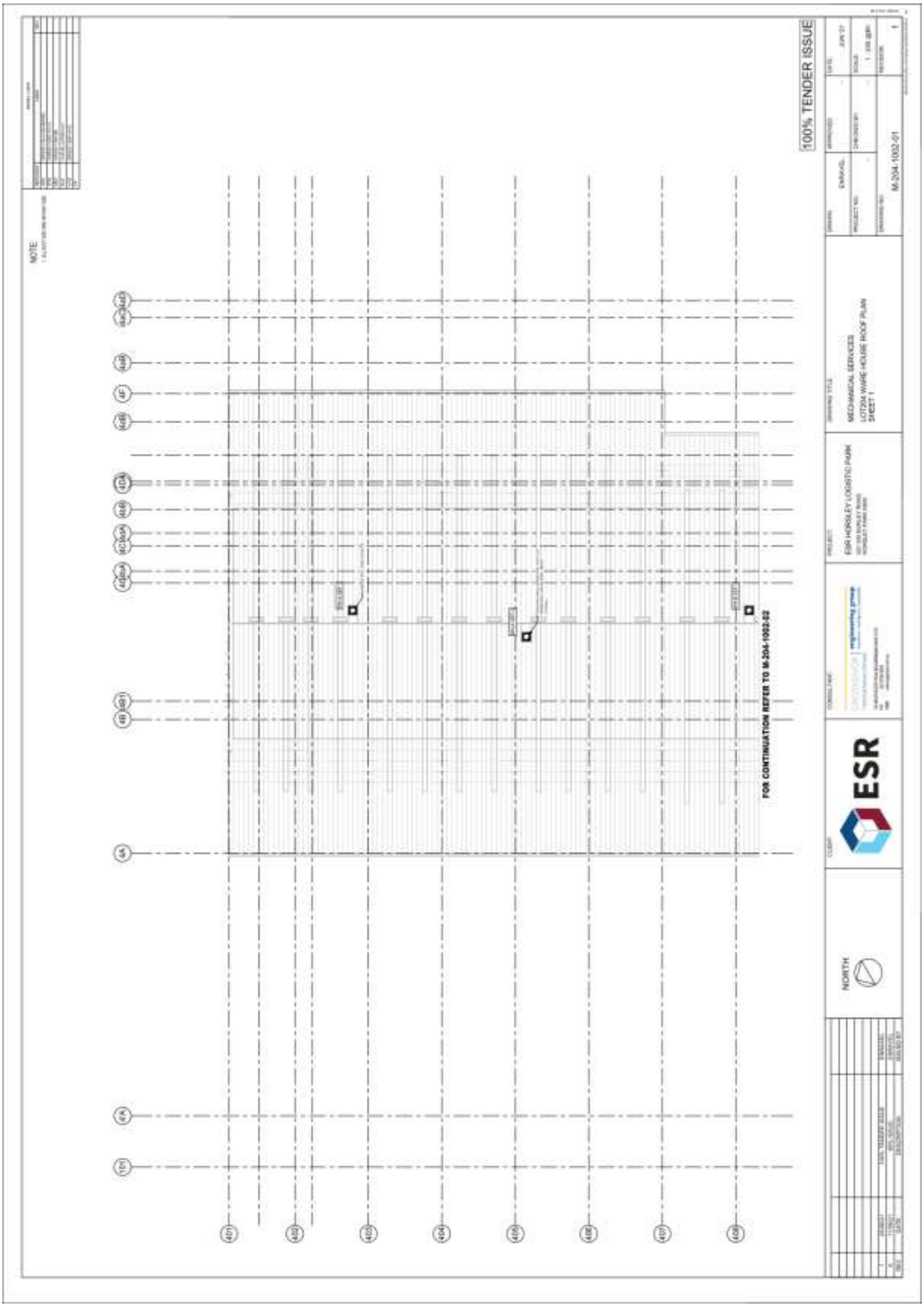
Appendix M. Fire Services Drawings

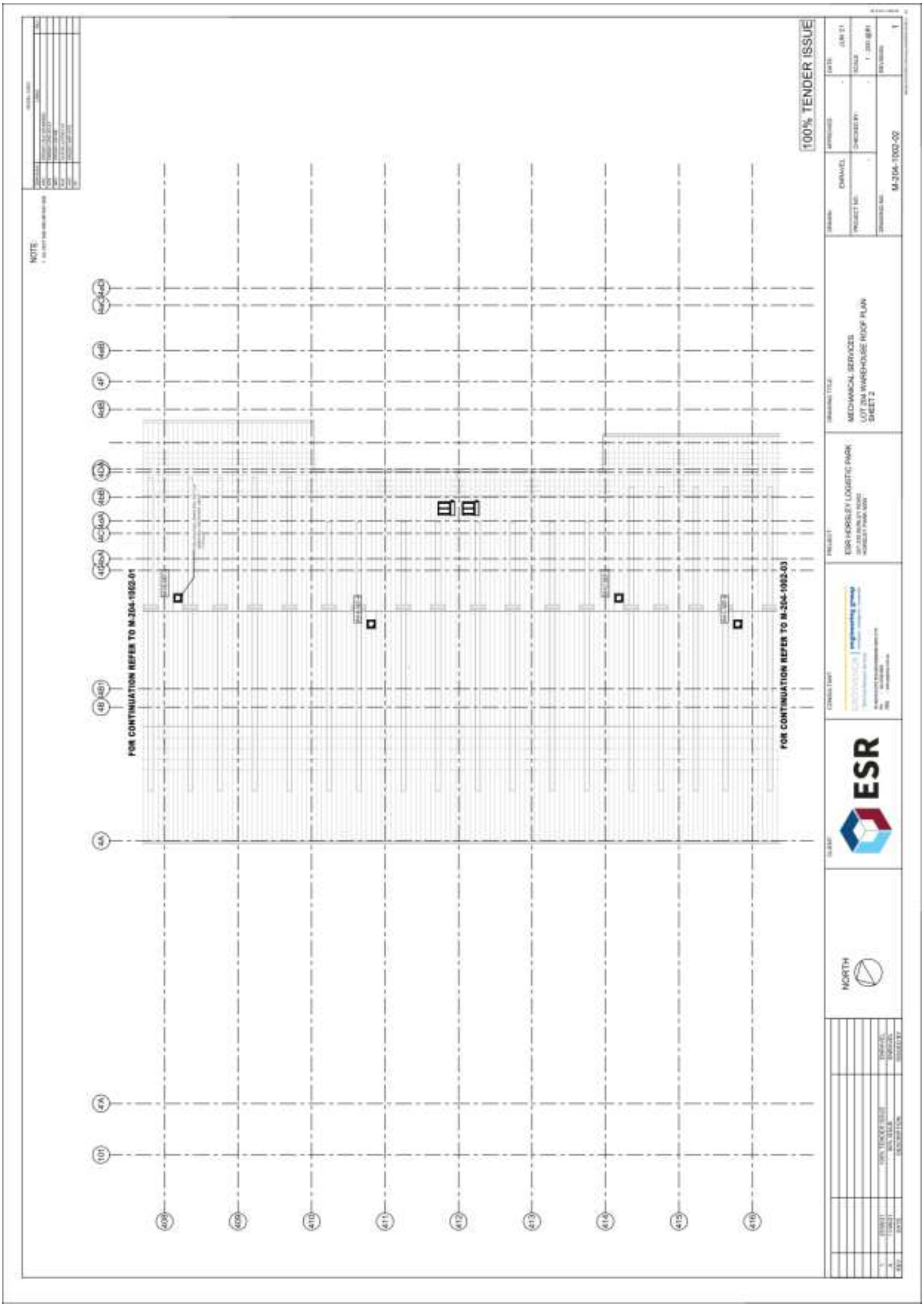


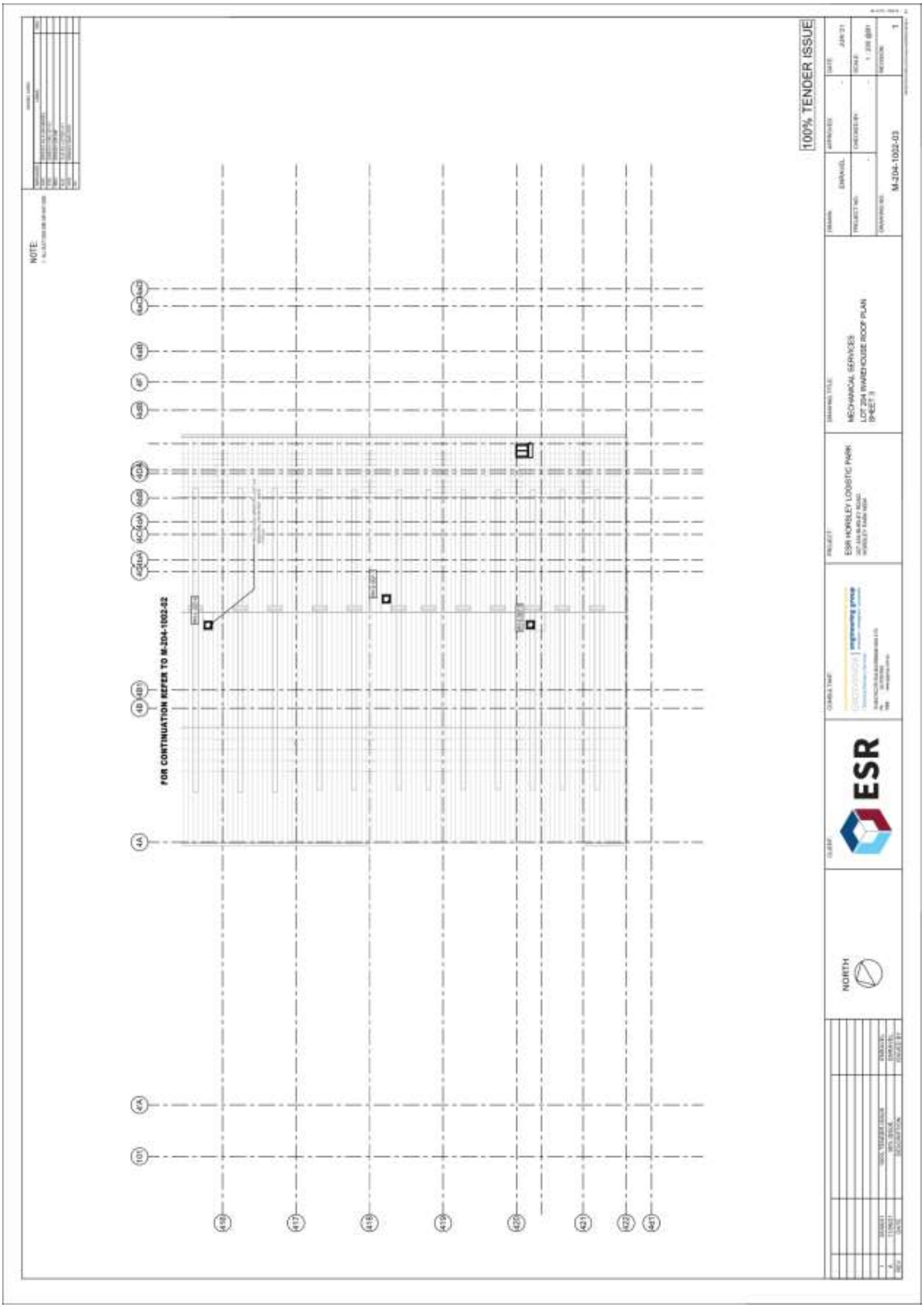



100% IFC ISSUE
SPARKS+PARTNERS
ESR
HANSENYUNCKEN
hlc

Appendix N. Mechanical Drawings




100% TENDER ISSUE
FOR CONTINUATION REFER TO M-204-1002-01
FOR CONTINUATION REFER TO M-204-1002-03
ESR
ESR HORSLEY LOGISTIC PARK
MECHANICAL SERVICES
LOT 204 WAREHOUSE ROOF PLAN
SHEET 2
M-204-1002-02
NORTH


100% TENDER ISSUE
FOR CONTINUATION REFER TO M-204-1002-02
NORTH
ESR
ESR HORSLEY LOGISTIC PARK
MECHANICAL SERVICES
LOT 204 WAREHOUSE ROOF PLAN
SHEET 3
M-204-1002-03