Preliminary Hazard Analysis

1 Woolworths Way, Warnervale NSW

Woolworths Ltd
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1 Woolworths Way, Warnervale NSW

Woolworths Ltd

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Rev	Date	Remarks	Prepared By	Reviewed By
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Executive Summary

Background

Woolworths Ltd (Woolworths) currently operates a warehouse located at 1 Woolworths Way, Warnervale, which is used to store, handle and redistribute a range of products to Woolworths stores. It has been proposed to expand the existing Wyong Retail Distribution Centre (RDC). As part of the expansion, it has been proposed to increase the quantity of Dangerous Goods (DGs) to be stored on site.

Where DGs are stored, the site is subject to the State Environmental Planning Policy No. 33 (SEPP 33, Ref. [1]) which aims to assess the risk posed by the site upon the adjacent land uses. The proposed quantities to be stored would exceed the SEPP 33 thresholds; hence, it is necessary to assess the risks posed in the form of a Preliminary Hazard Analysis (PHA) in accordance with the Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 and No. 6 (Ref. [2] & [3]) for submission with the Development Application (DA).

Woolworths has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare the PHA for the facility. This document represents the PHA study for the Woolworths Wyong RDC, located at 1 Woolworths Way, Warnervale.

Conclusions

A hazard identification table was developed for the warehouse facility to identify potential hazards that may be present at the site as a result of operations or storage of materials. Based on the identified hazards, scenarios were postulated that may result in an incident with a potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. Scenarios not eliminated were then carried forward for consequence analysis.

Incidents carried forward for consequence analysis were assessed in detail to estimate the impact distances. Impact distances were developed into scenario contours and overlaid onto the site layout diagram to determine if an offsite impact would occur. The consequence analysis showed that one of the scenarios (full warehouse fire) would impact over the site boundary and into the adjacent land use; hence, this incident was carried forward for frequency analysis and risk assessment.

The frequency analysis and risk assessment showed that the full warehouse fire would have a fatality risk of 7.06 chances per million per year (pmpy) at the site boundary, with lesser risk at further distances from the boundary. HIPAP No. 4 (Ref. [2]) publishes acceptable risk criteria at the site boundary of 50 pmpy (for industrial sites). Therefore, the probability of a fatality from a full warehouse fire at the site boundary is within the acceptable risk criteria.

In addition, it was found that no incidents would result in impacts to adjacent structures. It is noted that for a full warehouse fire, due to the fire size there will be considerable smoke emitted which would obscure the flame surface reducing the average surface emissive power (SEP) and subsequently it would not exceed 23 kW/m^2. In addition, the distance to the closest building is 50 m which would allow attenuation of radiant heat from of luminous spots and would not result in sustained radiant heat such that propagation to adjacent facilities would occur.

Based on the analysis conducted, it is concluded that the risks at the site boundary are not considered to exceed the acceptable risk criteria; hence, the facility would only be classified as potentially hazardous and would be permitted within the current land zoning for the site.

Recommendations

Notwithstanding the conclusions following the analysis of the facility, the following recommendations have been made:

- Spill kits shall be provided in all areas where DGs are stored to facilitate clean up response.
- The use of spill kits shall be incorporated into the site Emergency Response Plan (ERP).

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Abbreviations

Abbreviation	Description
ADG	Australian Dangerous Goods Code
AS	Australian Standard
BLEVE	Boiling Liquid Expanding Vapour Explosion
CBD	Central Business District
CCPS	Centre for Chemical Process Safety
DA	Development Application
DGs	Dangerous Goods
DGS	Dangerous Goods Store
DPE	Department of Planning and Environment
FRNSW	Fire and Rescue New South Wales
HIPAP	Hazardous Industry Planning Advisory Paper
HSE	Health and Safety Executive
LPG	Liquefied Petroleum Gas
PFD	Probability of Failure on Demand
PHA	Preliminary Hazard Analysis
Pmpy	Per million per year
RDC	Retail Distribution Centre
SEP	Surface Emissive Power
SEPP	State Environmental Planning Policy
SMSS	Storage Mode Sprinkler System
VCE	Vapour Cloud Explosion

1.0 Introduction

1.1 Background

Woolworths Ltd (Woolworths) currently operates a warehouse located at 1 Woolworths Way, Warnervale, which is used to store, handle and redistribute a range of products to Woolworths stores. It has been proposed to expand the existing Wyong Retail Distribution Centre (RDC). As part of the expansion, it has been proposed to increase the quantity of Dangerous Goods (DGs) to be stored on site.

Where DGs are stored, the site is subject to the State Environmental Planning Policy No. 33 (SEPP 33, Ref. [1]) which aims to assess the risk posed by the site upon the adjacent land uses. The proposed quantities to be stored would exceed the SEPP 33 thresholds; hence, it is necessary to assess the risks posed in the form of a Preliminary Hazard Analysis (PHA) in accordance with the Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 and No. 6 (Ref. [2] & [3]) for submission with the Development Application (DA).

Woolworths has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare the PHA for the facility. This document represents the PHA study for the Woolworths Wyong RDC, located at 1 Woolworths Way, Warnervale.

1.2 Objectives

The objectives of the PHA project include:

- Complete the PHA according to the Hazardous Industry Planning Advisory Paper (HIPAP) No. 6 – Hazard Analysis (Ref. [3]),
- Assess the PHA results using the criteria in HIPAP No. 4 – Risk Criteria for Land Use Planning (Ref. [1]), and
- Demonstrate compliance of the site with the relevant codes, standards and regulations (i.e. NSW Planning and Assessment Regulation 1979, WHS Regulation, 2011 Ref. [4]).

1.3 Scope of Services

The scope of work is to complete a PHA study for the Warehouse located at 1 Woolworths Way, Warnervale, required by the Planning Regulations. The scope does not include any other assessments at the site nor any other Woolworths facilities.

2.0 Methodology

2.1 Multi-Level Risk Assessment

The Multi-Level Risk Assessment approach (Ref. [4]) published by the NSW Department of Planning and Environment, has been used as the basis for the study to determine the level of risk assessment required. The approach considered the development in context of its location, the quantity and type (i.e. hazardous nature) Dangerous Goods stored and used, and the facility's technical and safety management control. The Multi-Level Risk Assessment Guidelines are intended to assist industry, consultants and the consent authorities to carry out and evaluate risk assessments at an appropriate level for the facility being studied.

There are three levels of risk assessment set out in Multi-Level Risk Assessment which may be appropriate for a PHA, as detailed in **Table 2-1**.

Table 2-1: Level of Assessment PHA

Level	Type of Analysis	Appropriate If:
1	Qualitative	No major off-site consequences and societal risk is negligible
2	Partially Quantitative	Off-site consequences but with low frequency of occurrence
3	Quantitative	Where 1 and 2 are exceeded

The Multi-Level Risk Assessment approach is schematically presented in **Figure 2-1**.

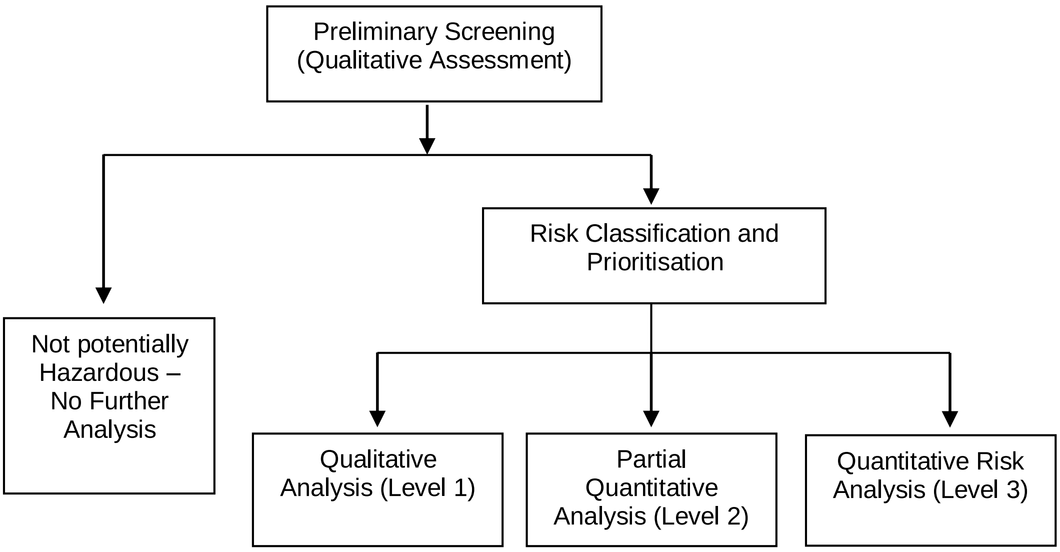

Figure 2-1: The Multi-Level Risk Assessment Approach

Based on the type of DGs to be used and handled at the proposed facility, a **Level 2 Assessment** was selected for the Site. This approach provides a qualitative assessment of those DGs of lesser quantities and hazard, and a quantitative approach for the more hazardous materials to be used on-site. This approach is commensurate with the methodologies recommended in "Applying SEPP 33's" Multi Level Risk Assessment approach (DPE, 2011).

2.2 Risk Assessment Study Approach

The methodology used for the PHA is as follows;

Hazard Analysis – A detailed hazard identification was conducted for the site facilities and operations. Where an incident was identified to have a potential off-site impact, it was included in the recorded hazard identification word diagram (**Appendix A**). The hazard identification word diagram lists incident type, causes, consequences and safeguards. This was performed using the word diagram format recommended in HIPAP No. 6 (Ref. [3]).

Each postulated hazardous incident was assessed qualitatively in light of proposed safeguards (technical and management controls). Where a potential offsite impact was identified, the incident was carried into the main report for further analysis. Where the qualitative review in the main report determined that the safeguards were adequate to control the hazard, or that the consequence would obviously have no offsite impact, no further analysis was performed. **Section 3.1** of this report provides details of values used to assist in selecting incidents required to be carried forward for further analysis.

Consequence Analysis – For those incidents qualitatively identified in the hazard analysis to have a potential offsite impact, a detailed consequence analysis was conducted. The analysis modelled the various postulated hazardous incidents and determined impact distances from the incident source. The results were compared to the consequence criteria listed in HIPAP No. 4 (Ref. [2]). The criteria selected for screening incidents is discussed in **Section 3.1**.

Where an incident was identified to result in an offsite impact, it was carried forward for frequency analysis. Where an incident was identified to not have an offsite impact, and a simple solution was evident (i.e. move the proposed equipment further away from the boundary), the solution was recommended, and no further analysis was performed.

Frequency Analysis – In the event a simple solution for managing consequence impacts was not evident, each incident identified to have potential offsite impact was subjected to a frequency analysis. The analysis considered the initiating event and probability of failure of the safeguards (both hardware and software). The results of the frequency analysis were then carried forward to the risk assessment and reduction stage for combination with the consequence analysis results.

Risk Assessment and Reduction – Where incidents were identified to impact offsite and where a consequence and frequency analysis was conducted, the consequence and frequency analysis for each incident were combined to determine the risk and then compared to the risk criteria published in HIPAP No. 4 (Ref. [2]). Where the criteria were exceeded, a review of the major risk contributors was performed, and the risks reassessed incorporating the recommended risk reduction measures. Recommendations were then made regarding risk reduction measures.

Reporting – on completion of the study, a draft report was developed for review and comment by Woolworths. A final report was then developed, incorporating the comments received by Woolworths for submission to the regulatory authority.

3.0 Site Description

3.1 Site Location

The site is located at 1 Woolworths Way, Warnervale which is located in the NSW Central Coast and is approximately 46 km southwest of the Newcastle Central Business District (CBD), and 70 km north of the Sydney CBD. **Figure 3-1** shows the regional location of the site. Provided in **Figure 3-2** is the layout of the site in Warnervale

Figure 3-1: Site Location

3.2 Adjacent Land Uses

The land is located in an industrial area surrounded by the following land uses, which are adjacent to the site:

- North – Industrial and Commercial Warehousing
- South – Warnervale Airport
- East – Warnervale Airport
- West – Industrial Warehousing (Sanitarium Warnervale)

3.3 Site Description

The facility is currently used to house Woolworths's retail distribution operations, which will involve the receival, storage and handling, and redistribution of a range of products, some of which are classified as Dangerous Goods. Goods are primarily delivered to the site via Warren Road, with some entering via Woolworths Way. All distribution truck exit the site via Warren Road.

The facility is currently comprised of the following areas:

- Warehouse – separated into a temperature controlled (TC) area and an ambient area.

- Refrigeration Plant Room
- Battery Charging Area
- Gatehouse, Offices and Amenities
- 485 space Car Park

It is proposed to extend both the ambient and TC warehouses, including the addition of 13 ethylene gas ripening rooms.

The ambient warehouse will store a range of DGs in retail packages and the facility will be designed to comply with the Retail Distribution Centre (RDC) section of AS/NZS 3833:2007 (Ref. [5]). These requirements account for the reduced risk posed by packages stored in restricted small volumes. The DGs will be arranged to provide required separation between different classes using non-DG products as 'filler' product within the segregation spaces. Separate bunding will be provided to ensure any spills between incompatible classes cannot occur. All DG products will be protected by base building specified Storage Mode Sprinkler System (SMSS) sprinklers designed according to AS 2118.1:2017 (Ref. [6]). All DG areas will be protected by hose reel coverage in addition to hydrant coverage. The warehouse will be naturally ventilated for occupation purposes which will provide adequate ventilation flow for preventing accumulation of any vapours released from packages in storage as required by AS/NZS 3833:2007 (Ref. [5]).

It is also proposed to build a Truck Wash Area and a Truck Maintenance Area. Acetylene (class 2.1), argon (class 2.2) and oxygen gas cylinders will be stored in the Truck Maintenance Area and the Welding Area for use in oxyacetylene welding. A range of motor oils (combustible liquids) will also be stored in this area.

A Liquefied Petroleum Gas (LPG) tank (4,500 L capacity) is currently located in the centre of the site at the site, adjacent to the car park and will remain in this location. As part of the proposed expansion, an above-ground integrally bunded Diesel Tank (50,000 L capacity) and AdBlue Tank (7,000 L) will be installed as part of the proposed truck refuelling area.

The site will be subject to a hazardous area classification per AS/NZS 60079.10.1:2009 (Ref. [7]) and any electrical equipment within the hazardous zone will be compliant per AS/NZS 60079.14:2017 (Ref. [8]) to minimise the potential for ignition of flammable vapours which may be released during storage.

3.4 Quantities of Dangerous Goods Stored and Handled

The dangerous goods stored at the warehouse are for various customers and may fluctuate with customer requirements. The classes and quantities to be approved in the facility are summarised **Table 3-1**. The proposed DG storage locations are shown in **Figure 3-2.**

Table 3-1: Maximum Classes and Quantities of Dangerous Goods Stored

Location	Class	Description	PG	Quantity
Above Ground Tank	2.1	Liquefied Petroleum Gas (LPG)	n/a	4,500 L / 2,475 kg^
Ripening Room	2.1	Ethylene Gas	n/a	100 L
Truck Maintenance Area	2.1	Acetylene	n/a	54 kg (1 x E-size)
	2.2 (5.1)	Oxygen	n/a	2.6 kg (1 x E-size)
	C1	Engine Oil / Lube Oil	n/a	2,170 L

Location	Class	Description	PG	Quantity
Welding Area	2.1	Acetylene	n/a	118 kg (1 x G-size)
	2.2	Argon	n/a	14.1 kg (1 x G-size)
	2.2 (5.1)	Oxygen	n/a	5.8 kg (1 x G-size)
Refrigeration Plant Room	2.3 (8)	Toxic Gas, with sub risk corrosive substance (Anhydrous Ammonia)	n/a	2,500 L
RDC Racking	2.1	Flammable gases (Aerosols)	n/a	32,744 kg*
	2.2	Non-flammable gases, non-toxic gases (Aerosols)	n/a	3,022 kg
	5.1	Oxidising agents	II	1 kg
			III	238 kg
	8	Corrosive substances	II	7,025 kg
			III	5,648 kg
Truck Refuelling Area	C1	Combustible Liquid (Diesel)	n/a	50,000 L

^Assumed density of LPG 550 kg/m^3 *Note: This refers to the quantity of propellant within the aerosols and not the total package weight. The propellant content within the cannisters is typically around 25% of product weight.

3.5 Aggregate Quantity Ratio

Where more than one class of dangerous goods are stored and handled at the site an AQR exists. This ratio is calculated using **Equation 3-1:**

$$AQR = \frac{q_x}{Q_x} + \frac{q_y}{Q_y} + [\dots] + \frac{q_n}{Q_n}$$ **Equation 3-1**

Where:

x,y […] and n are the dangerous goods present

q_x, q_y, […] and q_n is the total quantity of dangerous goods x, y, […] and n present.

Q_x, Q_y, […] and Q_n is the individual threshold quantity for each dangerous good of x, y, […] and n

Where the ratio AQR exceeds a value of 1, the site would be considered a Major Hazard Facility (MHF). The threshold quantity for each class is taken from Schedule 15 of the Work Health and Safety (WHS) Regulation 2017 (Ref. [9]). These are summarised in **Table 3-2** noting Class 2.2, Class 8 and C1 combustible liquids are not subject to MHF legislation.

Table 3-2: Major Hazard Facility Thresholds

Class	Description	PG	Threshold (tonnes)	Storage (tonnes)
2.1	Acetylene	n/a	50	0.17
2.1	Flammable Gases	n/a	200	35.3
2.2	Non-flammable, non-toxic gases	n/a	Not subject to MHF	3.08
2.2 (5.1)	Oxygen	n/a	2,000	0.01
2.3	Anhydrous Ammonia	n/a	200	2.50
5.1	Oxidising Materials	II & III	200	0.24

Class	Description	PG	Threshold (tonnes)	Storage (tonnes)
8	Corrosive Substances	II & III	Not subject to MHF	12.7
C1	Combustible Liquids (Diesel)	n/a	Not subject to MHF	52.2

A review of the thresholds and the commodities and packing groups listed in **Table 3-1** indicates only Class 2.1, 3, 5.1, and 6.1 are assessable against the MHF thresholds. Therefore, substituting the storage masses into **Equation 3-1** the AQR is calculated as follows:

$$AQR = \frac{0.17}{50} + \frac{35.3}{200} + \frac{0.01}{2{,}000} + \frac{2.5}{200} + \frac{0.24}{200} = 0.19$$

The AQR is less than 1; hence, the facility would not be classified as an MHF.

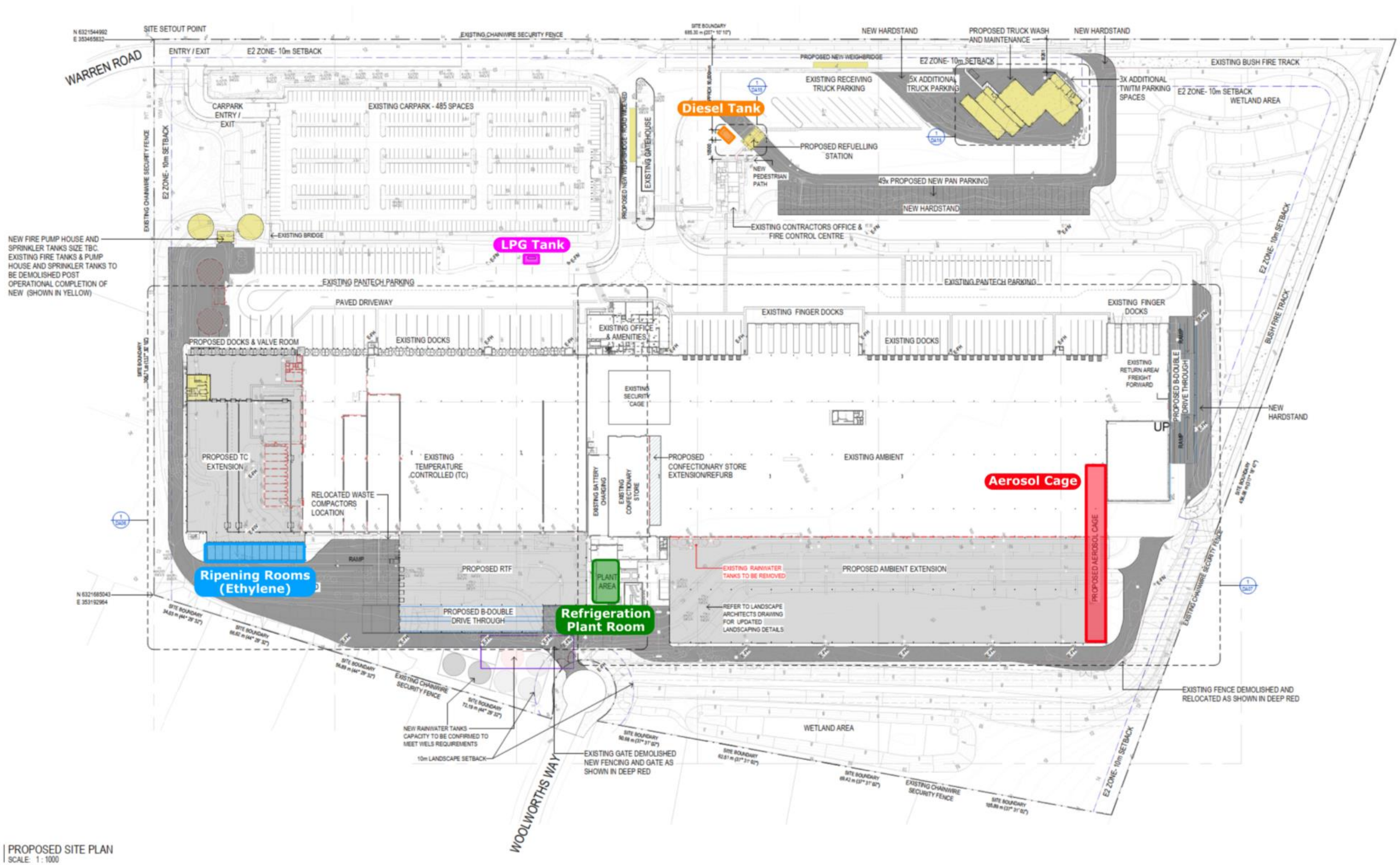

Figure 3-2: Site Layout

4.0 Hazard Identification

4.1 Introduction

A hazard identification table has been developed and is presented at **Appendix A**. This table has been developed following the recommended approach in Hazardous Industry Planning Advisory Paper No .6, Hazard Analysis Guidelines (Ref. [3]). The Hazard Identification Table provides a summary of the potential hazards, consequences and safeguards at the site. The table has been used to identify the hazards for further assessment in this section of the study. Each hazard is identified in detail and no hazards have been eliminated from assessment by qualitative risk assessment prior to detailed hazard assessment in this section of the study.

In order to determine acceptable impact criteria for incidents that would not be considered for further analysis, due to limited impact offsite, the following approach has been applied:

- *Fire Impacts* - It is noted in Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible heat radiation at the site boundary (4.7 kW/m^2) above which the risk of injury may occur and therefore the risk must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk, for this study, incidents that result in a heat radiation less that at 4.7 kW/m^2, at the site boundary, are screened from further assessment.

  Those incidents exceeding 4.7 kW/m^2 at the site boundary are carried forward for further assessment (i.e. frequency and risk). This is a conservative approach, as HIPAP No. 4 (Ref. [2]) indicates that values of heat radiation of 4.7 kW/m^2 should not exceed 50 chances per million per year at sensitive land uses (e.g. residential). It is noted that the closest residential area is more than several hundred meters from the site, hence, by selecting 4.7 kW/m^2 as the consequence impact criteria (at the adjacent industrial site boundary) the assessment is considered conservative.

- *Explosion* - It is noted in HIPAP No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible explosion over pressure at the site boundary (7 kPa) above which the risk of injury may occur and therefore the risk must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk, for this study, incidents that result in an explosion overpressure less than 7 kPa, at the site boundary, are screened from further assessment. Those incidents exceeding 7 kPa, at the site boundary, are carried forward for further assessment (i.e. frequency and risk). Similarly, to the heat radiation impact discussed above, this is conservative as the 7 kPa value listed in HIPAP No. 4 relates to residential areas, which are over more than several hundred meters from the site.

- *Toxicity* – Toxic substances have been proposed to be stored at the site; hence, toxicity has been assessed.

- *Property Damage and Accident Propagation* - It is noted in HIPAP No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible heat radiation/explosion overpressure at the site boundary (23 kW/m^2/14 kPa) above which the risk of property damage and accident propagation to neighbouring sites must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk to incident propagation, for this study, incidents that result in a heat radiation heat radiation less than 23 kW/m^2 and explosion over pressure less than 14 kPa, at the site boundary, are screened from further assessment. Those incidents exceeding 23 kW/m^2 at the site boundary are carried forward for further assessment with respect to incident propagation (i.e. frequency and risk).

- _Societal Risk_ – HIPAP No. 4 (Ref. [2]) discusses the application of societal risk to populations surrounding the proposed potentially hazardous facility. It is noted that HIPAP No. 4 indicates that where a development proposal involves a significant intensification of population, in the vicinity of such a facility, the change in societal risk needs to be taken into account. In the case of the facility, there is currently no significant intensification of population around the proposed site; however, the adjacent land has been rezoned residential; hence, there will be housing located approximately more than several hundred meters from the site. Therefore, societal risk has been considered in the assessment.

4.2 Properties of Dangerous Goods

The type of DGs and quantities stored and used at the site has been described in **Section 3**. **Table 4-1** provides a description of the DGs stored and handled at the site, including the Class and the hazardous material properties of the DG Class.

Table 4-1: Properties* of the Dangerous Goods and Materials Stored at the Site

Class	Hazardous Properties
2.1 – Flammable Gas	Class 2.1 includes flammable gases which are ignitable when in a mixture of 13 per cent or less by volume with air or have a flammable range with air of at least 12 percentage points regardless of the lower flammable limit. Ignited gas may result in explosion or flash fire. Where gas released under pressure from a hole in a pressurised component is ignited, a jet fire may occur. The explosive concentration limits for ethylene are 2.3% - 36.0% (Ref. [10]). Between these concentrations an ignition may result in fire or explosion depending upon the conditions. Ethylene is an organic plant hormone which can be used to accelerate ripening in fruits and vegetables. Typical ripening concentration is 100-150 ppm.
2.2 – Non-Flammable, Non-Toxic Gas	Class 2.2 includes non-flammable and non-toxic gases. These gases are which are potential asphyxiants, as they dilute or replace the oxygen normally in the atmosphere.
2.3 – Toxic gases (Anhydrous Ammonia)	Ammonia is a colourless toxic gas which is highly hydroscopic (i.e. water soluble). At an ammonia concentration of 0.5% (5,000 ppm, Ref. [11]) a fatality will occur within minutes of exposure. Within concentration limits of 15% – 33.6% (150,000 – 336,000 ppm, Ref. [10]) ammonia can ignite given the right conditions, resulting in fire and/or explosion. It is noted that ignition of ammonia is difficult and can only be achieved by a high-energy source. In addition, sustained ignition of ammonia (i.e. burning) rarely occurs as the heat of the flame is less than the heat of ignition. Ammonia is used as a raw material for the synthesis of fertilisers, cleaning agent or refrigeration.
5.1 – Oxidising Agents	Class 5.1 materials will not combust but these materials include substances which can in a fire event, liberate oxygen and could accelerate the burning of other combustible or flammable materials. Releases to the environment may cause damage to sensitive receptors within the environment.
8 – Corrosive Substances	Class 8 substances (corrosive substances) are substances which, by chemical action, could cause damage when in contact with living tissue (i.e. necrosis), or, in case of leakage, may materially damage, or even destroy, other goods which come into contact

Class	Hazardous Properties
	with the leaked corrosive material. Releases to the environment may cause damage to sensitive receptors within the environment.
C1 – Combustible Liquids	Combustible liquids are typically long chain hydrocarbons with flash points exceeding 60.5°C. Combustible liquids are difficult to ignite as the temperature of the liquid must be heated to above the flash point such that vapours are generated which can then ignite. This process requires either sustained heating or a high-energy ignition source.

* The Australian Code for the Transport of Dangerous Goods by Road and Rail (Ref. [12]).

4.3 Hazard Identification

Based on the hazard identification table presented in **Appendix A**, the following hazardous scenarios have been developed:

- Flammable gas release, delayed ignition and flash fire or explosion.
- LPG release (from aerosol), ignition and racking fire.
- Class 2.2 gas release, resulting in an oxygen depleted environment
- Oxygen cylinder release, during a fire and potential exacerbation of fire
- Ammonia release and toxic dispersion
- Ammonia release, accumulation and ignition and explosions
- Combustible liquid spill in the truck maintenance area, ignition and fire
- Full warehouse fire and radiant heat.
- Full warehouse fire and toxic smoke emission.
- Dangerous goods liquid spill, release and environmental incident.
- Warehouse fire, sprinkler activation and potentially contaminated water release.
- LPG release (from tank), ignition and pool fire.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire.
- LPG release (from tank) and ignition causing flash fire or explosion.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG delivery tanker and Boiling Liquid Expanding Vapour Explosion (BLEVE).
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG tank and BLEVE.
- Diesel tank leak/spill and environmental incident
- Diesel tank leak/spill, ignition and pool fire

Each identified scenario is discussed in further detail in the following sections.

4.4 Flammable Gas Cylinder Release, Ignition and Flash Fire or Explosion

Ethylene and Acetylene will be stored on site in cylinders. Ethylene will be used at the facility to ripen fruit and vegetables as required. The ripening process will occur within the ripening room which is temperature and humidity controlled specifically for the produce being ripened. Ethylene is then released at low concentrations into the space to stimulate ripening of the produce. Acetylene cylinders will be stored in the Truck Maintenance Area (1 x E-size) and in the Welding Area (1 x G-size), for use in oxy-acetylene welding. Ethylene and Acetylene are flammable gases; hence, there is the potential that if a release were to occur it could ignite as a fire or an explosion.

It is noted that under normal operational circumstances, ignition of ethylene in the ripening operation is not a credible outcome as the ethylene concentration is typically around 100-150 ppm while the lower explosive limit is 2,300 ppm. Therefore, under normal operation fire or explosion would not be considered to occur. This is substantiated by the low incidence of fire or explosion arising from ripening rooms. It is noted that the majority of supermarkets have some form of ripening room to finish the ripening process for fresh produce before being put out for sale.

Notwithstanding this, there is the potential for release of ethylene or acetylene to occur in abnormal operations (i.e. dropped cylinder, damaged valve, etc.) which could result in the release of flammable gas. However, due to the design, pressure testing, and protection systems incorporated into cylinder design and approval the potential for a catastrophic release to occur is limited. Credible release scenarios from cylinders would typically be cracks around valve stems or leaky valves resulting in relatively minor releases which would be insufficient to result in consequence impacts extending over the site boundary.

Furthermore, the storage of the cylinders would be classified as a minor storage under AS 4332-2004 (Ref. [13]) which is the lowest risk level for a storage containing cylinders. This acknowledges the potential consequences from such a storage small in nature, therefore indicating that an incident is unlikely to impact over the site boundary.

Moreover, in order for a gas cloud to explode it must be confined, it must accumulate within the explosive limits, and an ignition source must be present. The risk of explosion has been mitigated by ensuring all cylinder stores are adequately ventilated, thereby minimising the potential for the accumulation of gas above the lower explosive limits, and by eliminating ignition sources via compliance with AS/NZS 60079 series of standards. The stores shall be zoned as hazardous areas in accordance with AS/NSZ 60079.10.1:2009 (Ref. [7]), and all electrical equipment within the store shall be compliant with AS/NZS 600079.14:2017 (Ref. [8]). As vapour cloud will not be able to accumulate and ignition sources will be minimised, an explosion is unlikely to occur. The potential for a flash fire is similarly mitigated, by use of ventilation and eliminating ignition sources.

As the potential for an offsite incident to occur from the flammable gas cylinder storage is unlikely to result in consequences impacting over the site boundary, this incident has not been carried forward for further analysis.

4.5 LPG Release (from Aerosol), Ignition and Racking Fire

Aerosols containing Liquefied Petroleum Gas (LPG) as the propellant will be held at the site for storage and distribution. There is potential that an LPG release could occur in the warehouse area due to an accident (packages dropped from forklift, punctured by forklift tines). It is noted that the potential for a release of LPG is low as aerosol canisters are pressure tested during manufacture and filling, hence, release would predominately result from damaged product rather than the deterioration of a package. Packages are inspected upon delivery and an accident involving aerosols would trigger an additional inspection to verify that damage had not occurred prior to storage within the warehouse.

Notwithstanding this, there is the potential for a release of LPG to occur within the storage racking. In in the event of a release, a flammable gas cloud would immediately form as the LPG would instantly flash to gas following release from the canister. Due to the hazardous area rated equipment within the area and protocols, it is considered unlikely for an ignition to occur; however, in the event that an ignition of an LPG release did occur, and the cloud is confined (i.e. pallet racking and stored products), the vapour cloud may explode if ignited, or, if it is unconfined, it may result in a flash fire.

The fire would consume the packaging with the generated heat impacting the adjacent aerosols. As the LPG within the adjacent aerosols expands the canisters may rupture releasing LPG which would ignite and rocket the canister throughout the aerosol cage potentially spreading the fire.

As the fire grows, the SMSS is expected to activate to suppress the fire and cool adjacent packages to minimise the potential for aerosol rupture and rocketing. Activation of this system would control the fire within the sprinkler array.

A sprinkler-controlled fire within the aerosol racking would be unlikely to impact over the site boundary; notwithstanding this, this incident has been carried forward for consequence analysis.

4.6 Class 2.2 Gas Release, Oxygen Depleted Environment

Aerosols containing non-flammable, non-toxic gases (Class 2.2) as the propellant will be held at the site for storage and distribution. There is a potential for a release of Class 2.2 gases to occur from damaged packages. As noted in **Section 4.5**, the potential for a gas release is low as aerosol canister are pressure tested during manufacture and filling, and packages are inspected upon delivery to verify damaged canisters are not stored. Notwithstanding this, in the event of a release, these gases may accumulate resulting in an oxygen deprived environment, leading to asphyxiation and potential injuries or fatalities.

Class 2.2 gases in aerosol containers typically comprise 25% of the total volume of the container. Therefore, the quantity of gas released would be <1 L in the worst-case release. The associated vapour cloud formed by the release of gas would be insufficient to result in an oxygen deprived environment.

In addition to the aerosols stored in the warehouse, an argon gas cylinder will be stored within the Truck Maintenance Area (1 x E-size) for use in welding. This would be classified as a minor storage under AS 4332-2004 (Ref. [13]) which, as discussed in **Section 4.4**, indicates that the potential consequences from such a storage small in nature, and would be unlikely to impact over the site boundary.

Therefore, it is considered that a release of class 2.2 gas resulting in an asphyxiation hazard with offsite impact is not a credible scenario; hence, this incident has not been carried forward for further analysis.

4.7 Oxygen Cylinder Release During a Fire and Potential Exacerbation of Fire

Compressed oxygen cylinders (Class 2.2 sub-risk 5.1) are stored within the Truck Maintenance Area (1 x E-size) and the Welding Area (1 x G-size) for use in oxyacetylene welding. Oxidising substances may contribute to the combustion of other materials by providing sources of oxygen. Therefore, in the event a release occurs in conjunction with a fire, the gases may exacerbate the existing fire, leading to propagation in other areas, and potential injuries or fatalities.

Oxygen cylinders will be stored in accordance with AS 4332-2004 (Ref. [13]) such that they are segregated from flammable materials. Furthermore, the storage of the cylinders would be classified as a minor storage under AS 4332-2004 (Ref. [13]) which is the lowest risk level for a storage containing cylinders which acknowledges the potential consequences from such a storage small in nature. Hence, a store containing less than the minor storage quantities indicates that any release is unlikely to impact beyond the site boundary.

Therefore, it is considered that a release of oxygen resulting in propagation of a fire with offsite impact is not a credible scenario. Hence, this incident has not been carried forward for further analysis.

4.8 Ammonia Release and Toxic Dispersion

Anhydrous Ammonia will be stored in a bulk tank in the refrigeration plant room for use in the warehouse refrigeration system. Ammonia is classified as a Class 2.3 (toxic gas), with sub risk Class 8 (corrosive substance).

The inherent hazards of the ammonia refrigeration system arise from the toxic properties of the ammonia gas. Anhydrous ammonia is ammonia in a compressed and/or liquefied form. At atmospheric temperature and pressure ammonia is a pungent, colourless gas and its odour serves as its own warning agent. Ammonia gas is lighter than air but when released from liquid storage tanks it can behave as a heavier than air gas, depending on the fraction of entrained liquid droplets. If the droplet fraction is less than 4-8% the gas cloud would be less dense, whereas above a droplet fraction of 16-30% the cloud would be denser than air. Between these critical values, the density of the cloud is determined by the degree of dilution and humidity of the air.

The boiling point of ammonia is -33^{o}C at atmospheric pressure and it can be stored by refrigeration at this temperature or under pressure at ambient temperature.

The nature of ammonia can cause the gas to be lethal in quite low doses. It can cause varying degrees of irritation to the skin or mucous membranes and can temporarily damage the visual and respiratory systems. In sufficient concentrations, permanent damage or death would occur. Ammonia gas can dissolve in moisture on the skin and cause a painful burning sensation. In liquid form ammonia can seriously damage the skin.

When assessing the potential for toxic impacts it is necessary to review the concentration within the plume against the Emergency Response Planning Guidelines (EPRG) levels for the subject materials. These levels provide guidance on exposure concentrations for general populations, including susceptible populations over a range of exposure times to assist in the assessment of releases which may result in a toxic exposure.

Provided below is a summary of the EPRG tiers of exposure:

- **ERPG-3** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
- **ERPG-2** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.
- **ERPG-1** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odour.

Provided in **Table 4-2** is a summary of the concentration limits for each EPRG value for ammonia.

Table 4-2: Ammonia EPRG Concentrations

EPRG Tier	Translation	Concentration (ppm)
3	Fatality	1500
2	Injury	150
1	Irritation	25

Releases can occur due to leakage from mechanical failure of pipework, vessels, compressors etc., or due to maloperation etc. The main potential leak sources of loss of containment include:

- Mechanical damage to the vessels, pipework and associated fittings, compressors, heat exchangers and condensers.
- Corrosion of the ammonia equipment including the above components.
- Operational or maintenance errors (e.g. leaking flange gasket through incorrect installation) resulting in the release of ammonia liquid or gas.
- Relief valve operation (vented through water tank).

Because of the irritation caused by exposure to ammonia gas, early warning is often possible before damage is done. With such early warning, it is very unlikely that staff or people affected would remain in the area. Furthermore, at such low levels of detection (i.e. 25 ppm) there is very little chance of injury or fatality before people can escape. The main danger arises when the concentration builds up too rapidly for action to be taken or where shelter or escape is impossible. However, this is unlikely at the facility due to the installation of gas detectors.

Furthermore, the total quantity of ammonia stored is less than the SEPP 33 storage threshold outlined in 'Applying SEPP 33' (Ref. [1]). These thresholds have been developed to determine whether a store is considered 'potentially hazardous'. Hence, a store which contains less than the SEPP 33 storage threshold is unlikely to be potentially hazardous, and therefore indicates that any release is unlikely to impact beyond the site boundary.

Therefore, a release of ammonia is unlikely to have offsite impacts, and this scenario has not been carried forward for further assessment.

4.9 Ammonia Release, Accumulation and Ignition and Explosion

There is the potential for an ammonia release to occur within the compressor plant room and for ammonia to accumulate. In the event that the gas is not successfully vented, there is a potential for the cloud to ignite sometime after the release. Ammonia is explosive within the range of 15% to 33.6% in air. Hence, it is possible that the confined gas cloud may explode, destroying the compressor house and initiating a pressure wave which may have farther afield impacts. People may be seriously injured or killed by explosion overpressure or by missiles projected from the explosion site.

A review of the site protection systems indicates there are two levels of ammonia detection. Upon first detection of ammonia at 35 ppm, the ventilation system will operate to remove ammonia from the plant room along with a low priority alarm. If the concentration increases to 300 ppm, a secondary fan is operated along with a high priority alarm. Should the concentration increase to 20% of the LEL (30,000 ppm) the system will isolate to prevent ignition of ammonia gas. Therefore, if accumulation continues, all electrical equipment will be inactive; hence, ignition would not occur.

Furthermore, ammonia is extremely hard to ignite and is a relatively stable compound. It begins to dissociate at approximately 450°C at atmospheric pressure, and auto ignites at 630°C (Ref. [10]). Conditions favourable for ignition are seldom encountered during normal operation due to the high temperature of ignition required.

The likelihood of reaching a flammable mixture and the required ignition temperature is negligible. Hence this incident has not been carried forward for further assessment.

4.10 Combustible Liquid Spill, Ignition and Fire

Combustible liquids (motor oils and lubricants) shall be held in the Truck Maintenance Area for use by maintenance staff. There is potential that a combustible liquid spill could occur in the store due to an accident (packages dropped or punctured by forklift tines) or deterioration of packaging. In the event the spill is ignited, a pool fire may occur, which could propagate through the Truck Maintenance Area.

The stores containing combustible liquids shall be design in accordance with AS 1940-2017 (Ref. [14]), including first-attack firefighting equipment. A review of the product list to be stored indicates the products are small packages, therefore if a spill occurred, it would be identified by maintenance personnel working in the area, where it could be immediately cleaned up. If a fire were to occur from a package spill, it would initially be small, and could be managed by trained staff. It is also noted that combustible liquids do not emit flammable vapours at ambient temperatures and subsequently are difficult to ignite.

Based on the limited fire size and the nature of combustible liquid, the risks of this incident impacting over the site boundary are considered to be low. Hence, this incident has not been carried forward for further analysis.

4.11 Full Warehouse Fire and Radiant Heat

There is potential that if a fire occurred within the warehouse and the fire protection systems failed to activate, a small fire may escalate as radiant heat impacts adjacent packages resulting in deterioration and release of additional fuel. While it is considered unlikely for a fire to occur simultaneously with the sprinkler system failing to operate there is the potential for this scenario to occur. Therefore, this incident has been carried forward for further analysis.

4.12 Full Warehouse Fire and Toxic Smoke Emission

As discussed in **Section 4.11** there is the potential for a full warehouse fire to occur in the event of sprinkler failure. During combustion toxic products of combustion may be generated which will be dispersed in the smoke plume which may impact downwind from the site. Depending on the toxicity of the bi-products, this may result in injury or fatality. Therefore, this incident has been carried forward for further analysis.

4.13 Dangerous Goods Liquid Spill, Release and Environmental Incident

There is potential that a spill of liquid DGs (Class 5.1, 8 and C1) could occur at the site due to an accident (packages dropped from forklift, punctured by forklift tines), or from a damaged/deteriorated package. It is noted that packages are inspected upon delivery to verify that damage had not occurred prior to storage within the warehouse. In the event that a spill occurs, and it is not contained, DGs could be released into the public water course resulting in a potential environmental incident.

All DG packages stored in the warehouse are in small retail size packages (>20 L), therefore in the event of a release, the full volume of the packages would be contained within the warehouse area. This is supported by the design requirements for retail distribution centres outlined in AS/NZS 3833:2007 (Ref. [5]), which does not require DG stores containing retail size packages to have bunding.

Therefore, a release within warehouse area would not result in an offsite release; hence, this incident has not been carried forward for further analysis.

Notwithstanding this, the following recommendations have been made:

- Spill kits shall be provided in all areas where DGs are stored to facilitate clean up response.
- The use of spill kits shall be incorporated into the site Emergency Response Plan (ERP).

4.14 LPG Release, Ignition and Pool Fire

In the event of a small leak from a vessel or pipework a pool of LPG may form when the rate of evaporation of LPG is less than the flow rate of LPG from the leak. If the pool were to ignite an LPG pool fire would occur which may impact over the site boundary.

The potential for a leak to occur which is sufficient to cause a release that exceeds the evaporation rate and to develop a pool large enough to ignite (noting the area is zoned per the requirements of AS/NZS 60079.10.1:2009, Ref. [7]) and the subsequent fire to impact over the site boundary is very low. This is substantiated by numerous similar sized LPG tanks installed throughout Australia with very low incidences of leaks and fires occurring from such installations.

While the potential for a leak and LPG pool and subsequent ignition to occur is incredibly low, the tank is located near the eastern site boundary; hence, there is the potential for an offsite impact. Therefore, this incident has been carried forward for further analysis.

4.15 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire

As the site LPG is depleted, it will be refilled by a delivery tanker at the site. During loading of the tank there is the potential for the hose to rupture which may be the result of a puncture of the hosing or deterioration through general wear and tear. It has been assumed the hoses are inspected monthly and pressure tested annually in accordance with the Australian Dangerous Goods Code (ADG, Ref. [15]).

Notwithstanding this, there is the potential for a hose to become damaged between inspection and test periods which may lead to sufficient deterioration resulting in a hose rupture when transferring pressurised LPG. Excess flow and non-return valves will isolate the flow of LPG; however, if these fail in addition to a hose rupture, LPG will be released resulting in an LPG vapour cloud. The operator may be able to respond and isolate the LPG transfer by activating an emergency stop button located on the tanker.

If the operator is incapacitated or unable to stop the transfer, the LPG will continue to flow developing a substantial cloud which may contact an ignition source and ignite, which would result in a flash fire or explosion which would burn back to the release point and subsequent jet fire. It is noted the area is unconfined; hence, an explosion is unlikely to occur and would likely result in a flash fire.

The potential for a fatality to occur as a result of a flash fire is not considered credible as the mechanism for a fatality to occur from a flash fire is via the combustion of flammable vapours at head height which results in oxygen within the lungs being consumed as the fuel burns. The impacted person will involuntarily inhale, as low oxygen is detected, resulting in inhalation of hot combustion products which burn the sensitive lining of the lungs. As LPG is a dense gas, any release will spread along at ground level and due to the open nature of the site it will not accumulate to a level where a person offsite will be fully engulfed; hence, a fatality is unlikely to occur.

While a flash fire may not be expected to cause significant harm, the impacts from a jet fire are likely to be substantial and would impact over the site boundary; hence, this incident has been carried forward for further analysis.

4.16 LPG Release and Ignition Causing Flash Fire or Explosion

In the event of an LPG release from the tank, LPG will vapourise forming a flammable atmosphere which may ignite. A review of the area indicates the tank will not be stored in an area where confinement will occur; hence, the atmosphere would not ignite as an explosion but would rather result in a flash fire.

As noted in **Section 4.15**, the mechanism for a fatality to occur from a flash fire is inhalation of hot combustion products when a person is fully engulfed in a vapour cloud when ignition occurs. As LPG is a dense gas it will spread out at ground level as there is no confinement to allow the gas to accumulate at height; therefore, it is unlikely that a vapour cloud would form to allow a person to be fully engulfed; hence, a fatality would be unlikely to occur.

Furthermore, AS/NZS 1596:2014 (Ref. [16]) has been developed with reference to the likely impact scenarios from storage of LPG in various tank sizes. Review of Table 6.1 of AS/NZS 1596:2014 (Ref. [16]) indicates for a 4.5 kL tank the separation distance to a protected place is approximately 5 m. Therefore, the standard would consider that in open air, events resulting from a release from the tank would be unlikely to significantly impact >5 m.

A catastrophic failure of an LPG tank (i.e. rupture and full release of LPG) is considered incredible due to the manufacturing and regular testing of pressure vessels according to AS 1210:2010 (Ref. [17]).

As the area is unconfined and the location of the tank provides adequate separation to the site boundary and protected places, it is considered that a fatality would not result from this incident.

Notwithstanding the above, the tank is located close to the eastern site boundary; hence, there is the potential for an offsite impact. Therefore, this incident has been carried forward for further analysis.

4.17 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Delivery Tanker and BLEVE

Similarly, to the scenario described in **Section 4.15,** the hose may rupture resulting in a jet fire. If this jet fire were aimed at the delivery tanker, the tanker shell would begin to heat, transferring the heat into the LPG within the tank which would begin to vaporise and increase the pressure within the tanker. At the design pressure of the tank, the pressure relief valve will begin to lift to relieve pressure within the tanker.

As the liquid level within the tanker drops, the impact zone of the jet fire may impact the vapour space in the tanker. The vapour will absorb less energy than the liquid which will result in localised heating of the tanker shell at the point of the jet fire impact. This may compromise the structural integrity of the tanker shell, which may rupture, resulting in a blast overpressure as the vessel fails.

This subsequently causes the formation of an LPG vapour cloud which may also ignite, resulting in a vapour cloud explosion known as a Boiling Liquid Expanding Vapour Explosion (BLEVE). This incident has been carried forward to assess the potential impact zone.

4.18 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Tank and BLEVE

Similarly, to the scenario described in **Section 4.15,** the hose may rupture resulting in a jet fire. If this jet fire were aimed at the tank, the tank shell would begin to heat, transferring the heat into the LPG within the tank which would begin to vaporise and increase the pressure within the tank which may result in a BLEVE as described in **Section 4.17**. Hence this incident has been carried forward for further analysis.

4.19 Diesel Tank, Damage and Release, Ignition and Fire

Diesel will be stored in an integrally bunded tank for adjacent to the Truck Refuelling Area. There is potential for a release of diesel to occur, which if ignited may result in a pool fire. It is noted that diesel is classified as a combustible liquid; hence, it does not emit flammable vapours at ambient temperatures and subsequently it is difficult to ignite.

There is potential for a spill to occur if the tank overfill sensors and alarms fail and the operator fails to respond to an overfill. However, the tank will be designed according to Clause 5.9 of AS 1940:2017 (Ref. [14]); hence, the tank will be capable of containing the full volume of the liquid within the separate tank, should deterioration of the internal tank or overfill occur.

A release may also occur if a vehicle were to impact the tanks as this may damage both the primary and secondary tanks. The diesel tank will be protected by impact protection which will prevent any wayward vehicles from contacting the tank; hence, catastrophic damage is unlikely to occur.

As the tanks have been designed to fully contain failure of the internal tank, the potential for releases externally to the tank is considered to be low. In addition, the potential for diesel to ignite is very low due to the high flash point; therefore, this incident has not been carried forward for further analysis.

4.20 Diesel Tank, Damage and Release to Environment

As discussed in **Section 4.19**, the potential for diesel to spill externally to the tank is low due to the integrally bunded nature of the tanks, the overfill protections, trained operators being present during transfers and impact protection. Therefore, a major release of diesel is not considered a credible event and is not carried forward for further analysis

5.0 Consequence Analysis

The following incidents were identified to have potential to impact off site:

5.1 Incidents Carried Forward for Consequence Analysis

The following incidents were identified to have potential to impact off site:

- LPG release (from aerosol), ignition and racking fire.
- Full warehouse fire and radiant heat.
- Full warehouse fire and toxic smoke emission.
- LPG release, ignition and pool fire.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire.
- LPG release and ignition causing flash fire or explosion.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG delivery tanker and BLEVE
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG tank and BLEVE.

Each incident has been assessed in the following sections.

5.2 LPG Release (from Aerosol), Ignition and Racking Fire

A damaged aerosol canister could result in the release of LPG which if ignited may result in a fire. As the fire grows the radiant heat may impact adjacent aerosol storage heating the LPG within aerosol cans which may rupture rocketing the canisters around the aerosol store. The heat generated from the fire will activate the SMSS which will suppress and control the fire while cooling adjacent packages minimising the potential for lateral fire spread due to radiant heat. A detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are presented in **Table 5-1** with the contours illustrated in **Figure 5-1.**

Table 5-1: Heat Radiation from an Aerosol Racking Fire

Heat Radiation (kW/m^2)	Distance (m)	
	Base Case	Sensitivity
35	6.0	13.0
23	7.0	16.0
12.6	9.0	22.0
4.7	14.0	34.0

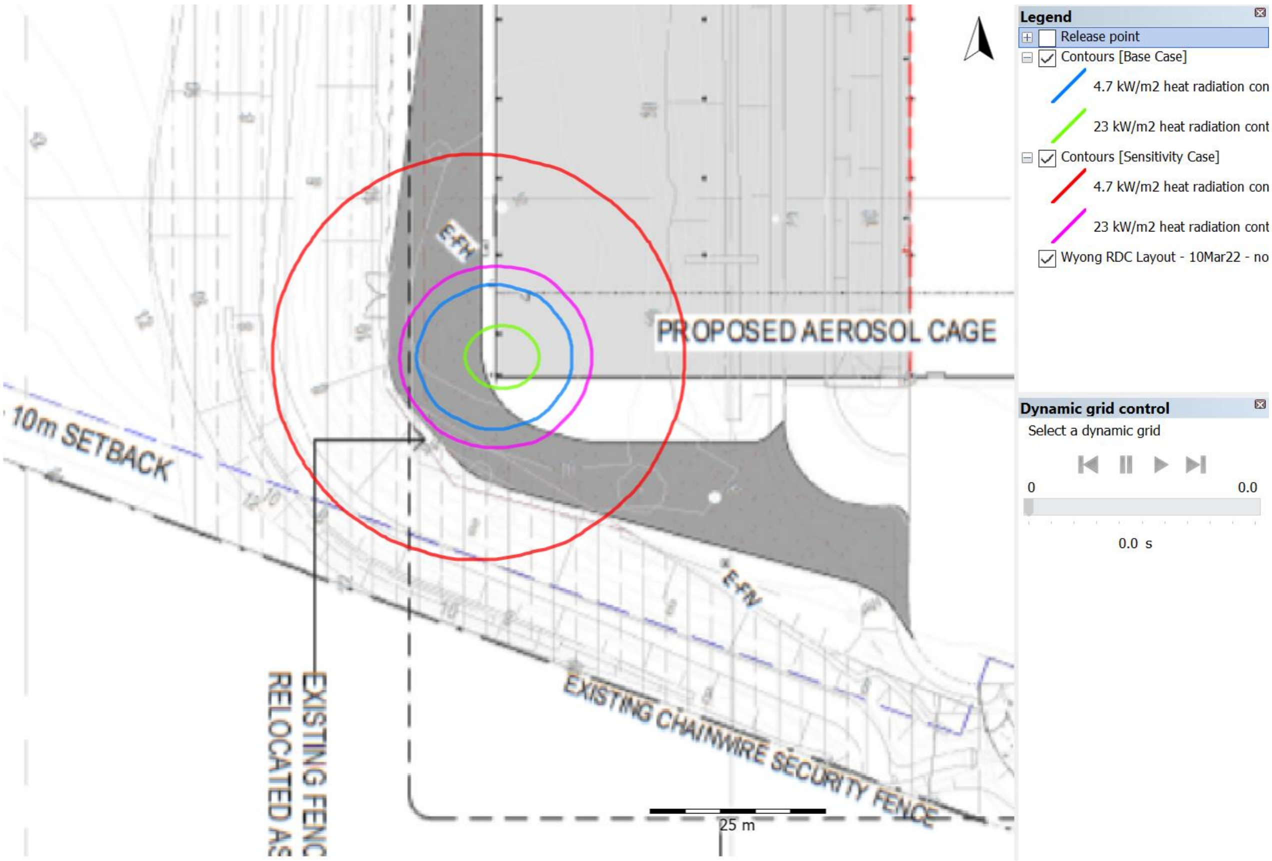

Figure 5-1: Sprinkler Controlled Aerosol Fire Radiant Heat Contours

A review of the contours illustrated in **Figure 5-1** indicates that neither the 4.7 nor the 23 kW/m^2 contours impact over the site boundary. As there is no offsite impact, this incident has not been carried forward for further analysis.

5.3 Full Warehouse Fire and Radiant Heat

If a fire occurs within the DG store and the sprinkler systems fail to activate, the fire will spread throughout the warehouse and is unlikely to be contained and would likely consume the entire warehouse. A detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are presented in **Table 5-2**. Due to the high aspect ratio of the warehouse, the warehouse modelling was separated into the northern and southern warehouse.

Table 5-2: Radiant Heat Impact Distances from a Full Warehouse Fire

Heat Radiation (kW/m^2)	Distance (m)	
	North	South
35	64	66
23	71	73
12.6	94	102
4.7	155	180

As shown in **Figure 5-2**, the radiant heat impacts at 4.7 kW/m^2 extend over the site boundary; hence, there is the potential for a fatality at the site boundary to occur. Therefore, this incident has been carried forward for further analysis.

It is noted that due to the fire size there will be considerable smoke emitted which would obscure the flame surface reducing the average surface emissive power (SEP) and subsequently it would not exceed 23 kW/m^2. In addition, the distance to the closest building is 50 m which would allow attenuation of radiant heat from of luminous spots and would not result in sustained radiant heat such that propagation to adjacent facilities would not occur.

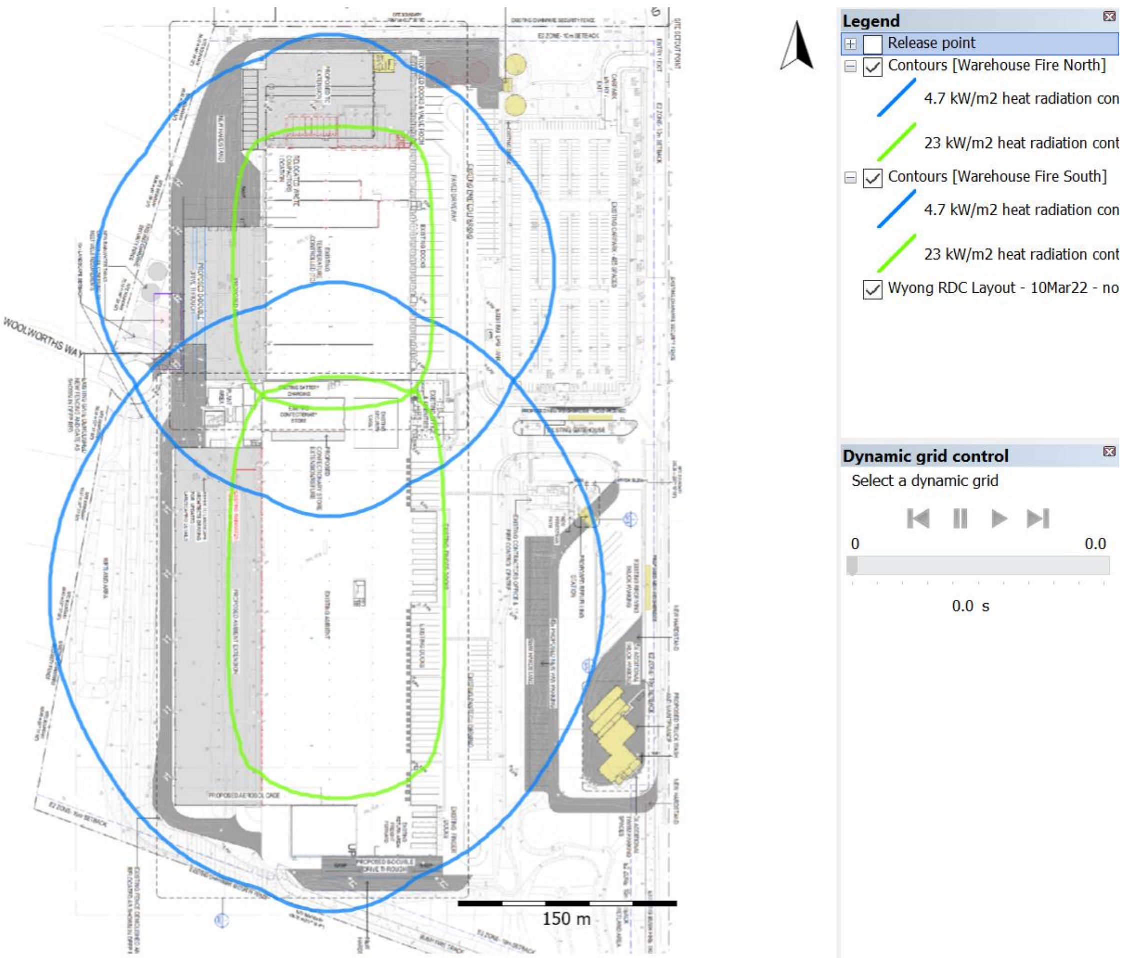

Figure 5-2: Full Warehouse Fire Radiant Heat Contours

5.4 Full Warehouse Fire and Toxic Smoke Emission

A detailed analysis has been performed in **Section B6** of **Appendix B** to estimate the impact of toxic bi-products of combustion on the surrounding area. The modelling identified four (4) primary pollutants of concern which may result in downwind impacts; nitrogen dioxide, sulphur dioxide, hydrogen chloride, and soot (carbon) with soot being more for visual disturbance to the surrounding area. The pollutant rates calculated for each pollutant has been shown in **Table 5-3**.

Table 5-3: Full Warehouse Fire Pollutant Release Rates

Material	Release Rate (kg/s)
Nitrogen Dioxide	88.2
Sulphur Dioxide	152.7
Hydrogen Chloride	77.5
Soot (Carbon)	175.2

The model calculates the interaction of the plume with the inversion layer to determine whether a ground level impact would occur from a warehouse fire. The results of the analysis indicates that the heat generated from the fire would be sufficient to pierce the inversion irrespective of the atmospheric stability. As the plume cools it will settle above the inversion layer but would not re-enter below the inversion layer. Therefore, ground level impact is not expected to occur from the warehouse fire.

As the plume would not impact at ground level, the potential for injury or fatality is considered negligible and be unlikely to exceed the acceptable criteria. Notwithstanding the low potential for injury or fatality to occur downwind, this incident has been carried forward for conservatism.

5.5 LPG Release, Ignition and Pool Fire

As discussed in **Section 4.14,** there is the potential for a release of flammable liquid to occur within the ISO-Container bund area which if ignited would result in a pool fire and associated radiant heat impacts. A detailed analysis has been performed in **Appendix B7** with the results summarised in **Table 5-4**.

Table 5-4: Heat Radiation from an LPG Pool Fire

Radiant Heat (kW/m^2)	Distance (m)
35	30
23	37
12.6	50
127	78

A review of the contours illustrated in **Figure 5-3** indicates that neither the 4.7 nor the 23 kW/m^2 contours impact over the site boundary. As there is no offsite impact, this incident has not been carried forward for further analysis.

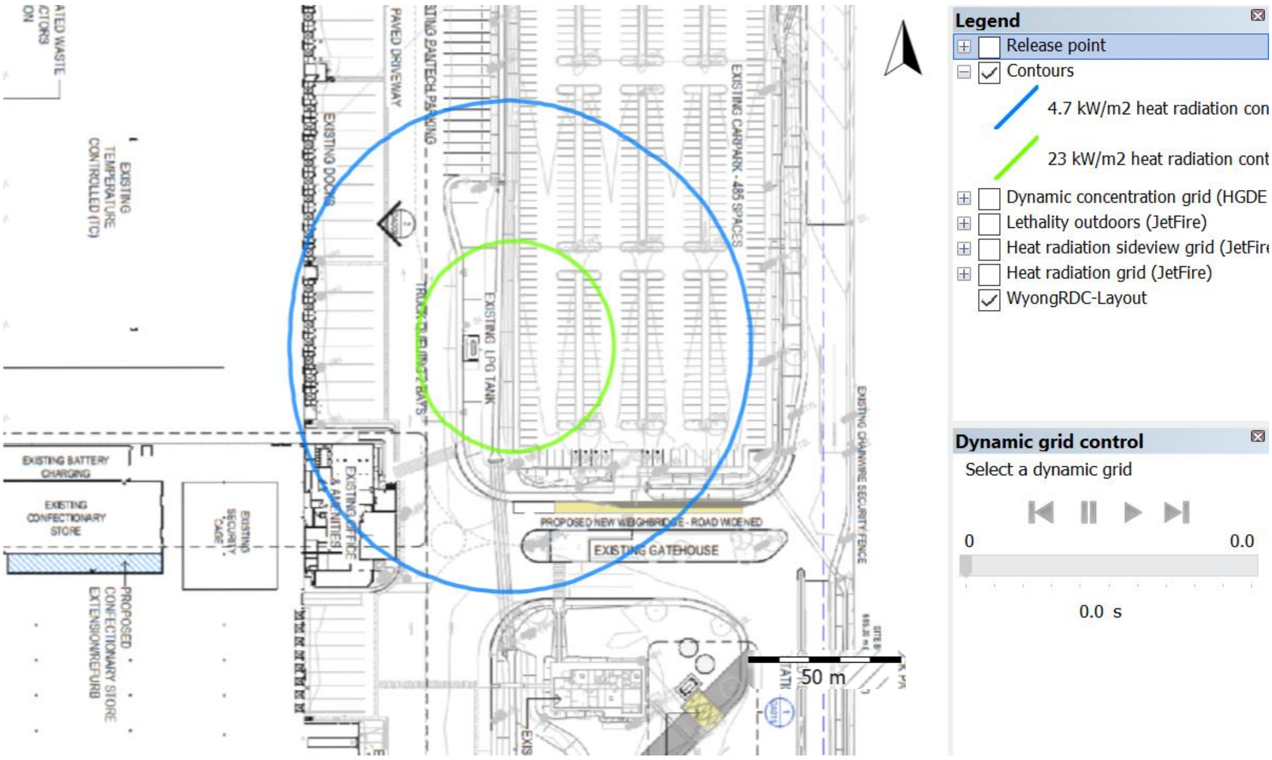

Figure 5-3: LPG Pool Fire Radiant Heat Contours

5.6 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire

As discussed in **Section 4.15,** there is the potential for a release of flammable liquid to occur within the ISO-Container bund area which if ignited immediately would result in a jet fire and associated radiant heat impacts. A detailed analysis has been performed in **Appendix B8** with the results summarised in **Table 5-5.**

Table 5-5: Heat Radiation from an LPG Jet Fire

Radiant Heat (kW/m^2)	Distance (m)
35	22
23	29
12.6	40
4.7	62

A review of the contours illustrated in **Figure 5-4** indicates that that neither the 4.7 kW/m^2 nor the 23 kW/m^2 contours impact offsite; hence, this incident has not been carried forward for further analysis.

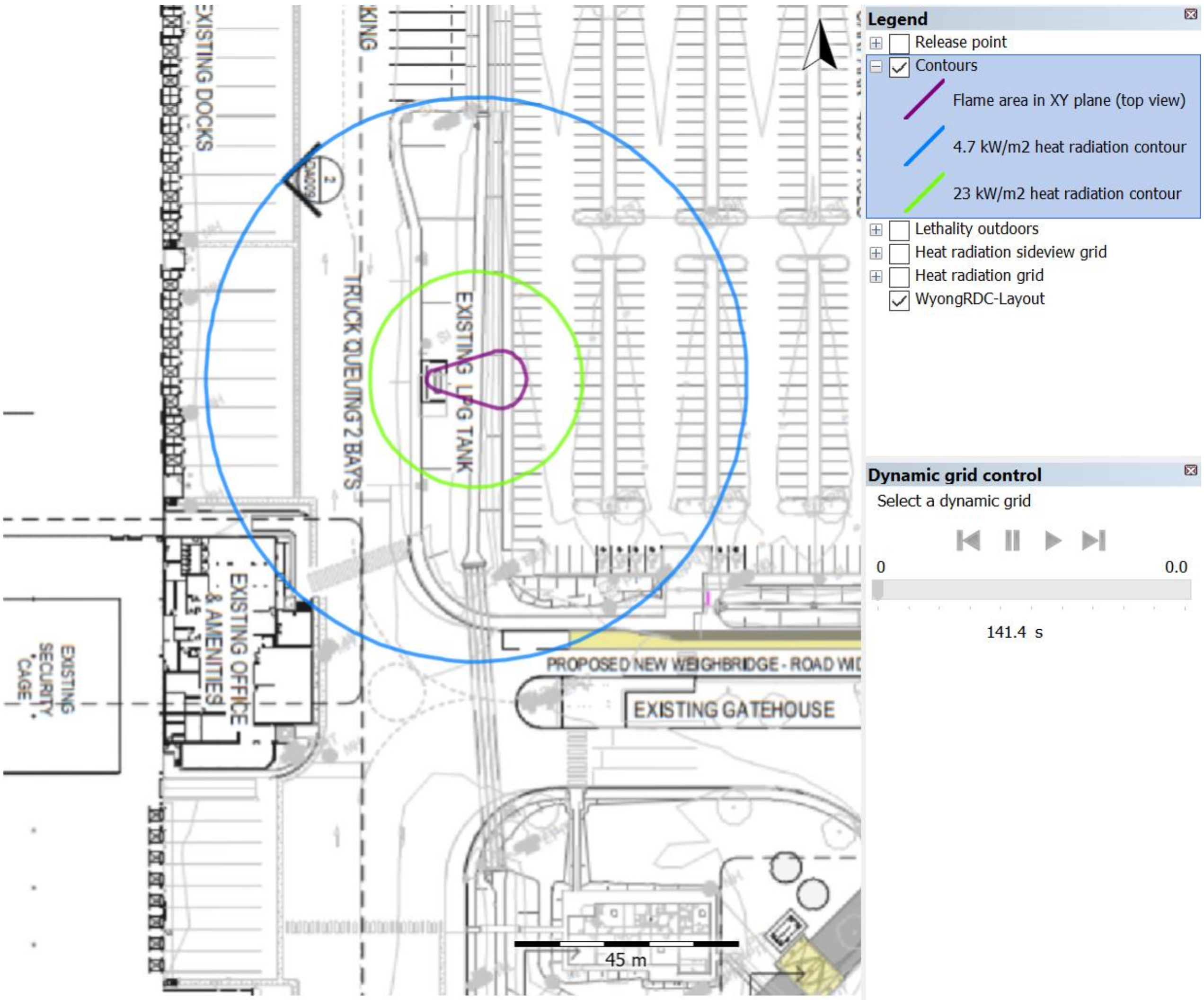

Figure 5-4: LPG Jet Fire Radiant Heat Contours

5.7 LPG Release and Ignition Causing Flash Fire or Explosion

5.7.1 LPG Flash Fire

As discussed in **Section 4.16,** there is the potential for a release of flammable liquid to occur within the LPG area which would disperse downwind and if delayed ignition occurred it would result in a flash fire.

A detailed analysis has been performed in **Appendix B9** with the results summarised in **Table 5-6** detailing the dimensions of the plume and the associated area of impact should the plume ignite resulting in a flash fire.

Table 5-6: LPG Release Flammable Atmosphere Plume Dimensions

Item	Dimension (m)
Cloud downwind distance to LFL	49.2
Cloud width to LFL	60.2

The outline of the downwind dispersion to the Lower Flammability Limit (LFL) has been provided in **Figure 5-5**. As can be seen, the 50% LFL of the plume does not impact over the site boundary; hence, an offsite fatality would not occur in the event of ignition. As there is no potential for an offsite impact, this incident has not been carried forward for further analysis.

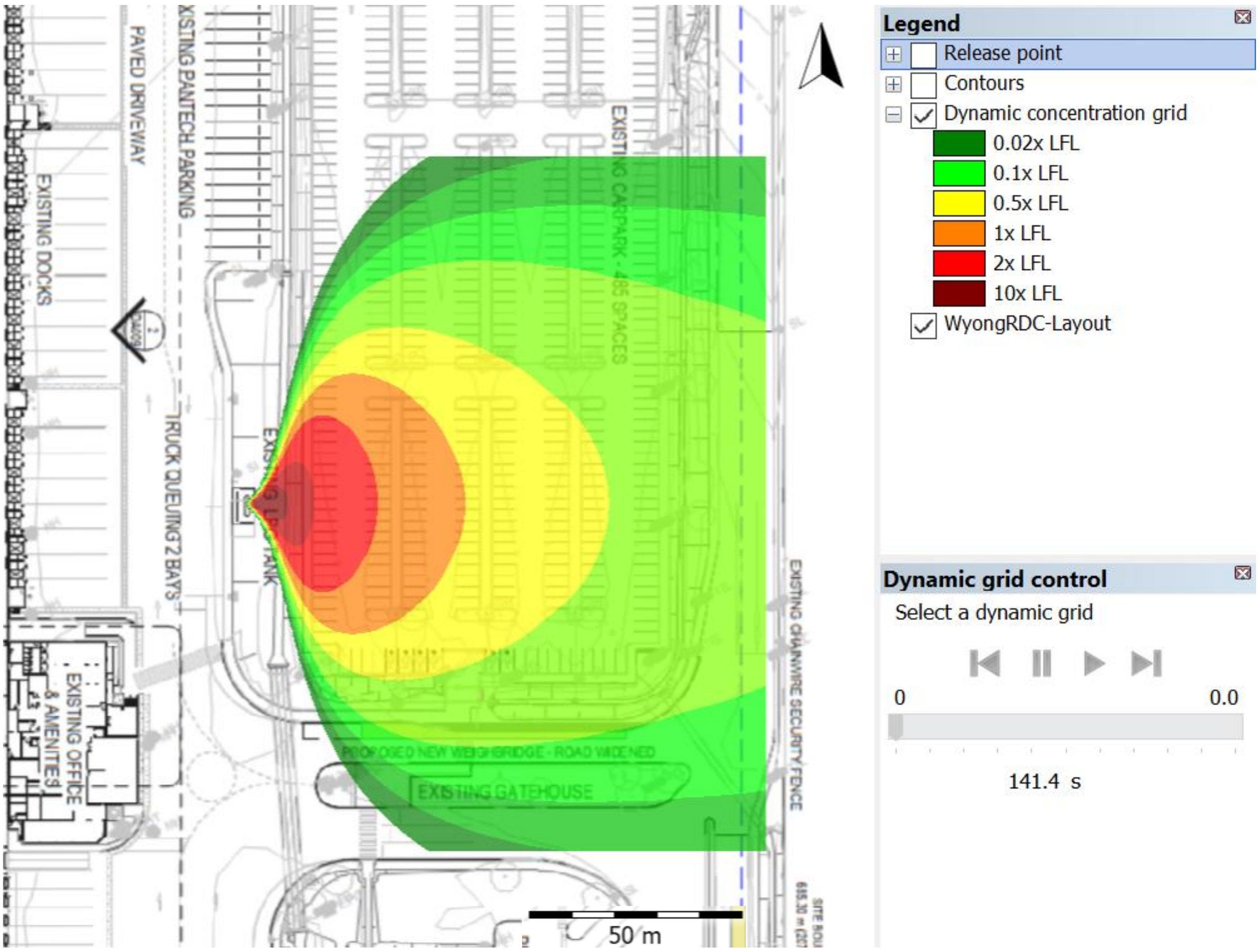

Figure 5-5: LPG Release Flash Fire Impact Distance

5.7.2 LPG Explosion

As discussed in **Section 4.16,** there is the potential for a release of flammable liquid to occur within the LPG area which would disperse downwind and if delayed ignition occurred it could result in an explosion. A detailed analysis has been performed in **Appendix B9** with the results summarised in **Table 5-7.**

Table 5-7: Overpressure Impacts from an LPG Release Explosion

Heat Radiation (kW/m^2)	Distance (m)
70	Not observed
35	Not observed
21	Not observed
14	Not observed
7	57

The overpressure contours associated with an ignition of the LPG plume resulting in explosion is shown in **Figure 5-6**. As can be seen, the overpressure at 7 kPa (70 mbar) does not impact over the site boundary. Therefore, the potential for a fatality to occur offsite from an LPG explosion could not occur; hence, this incident has not been carried forward for further analysis.

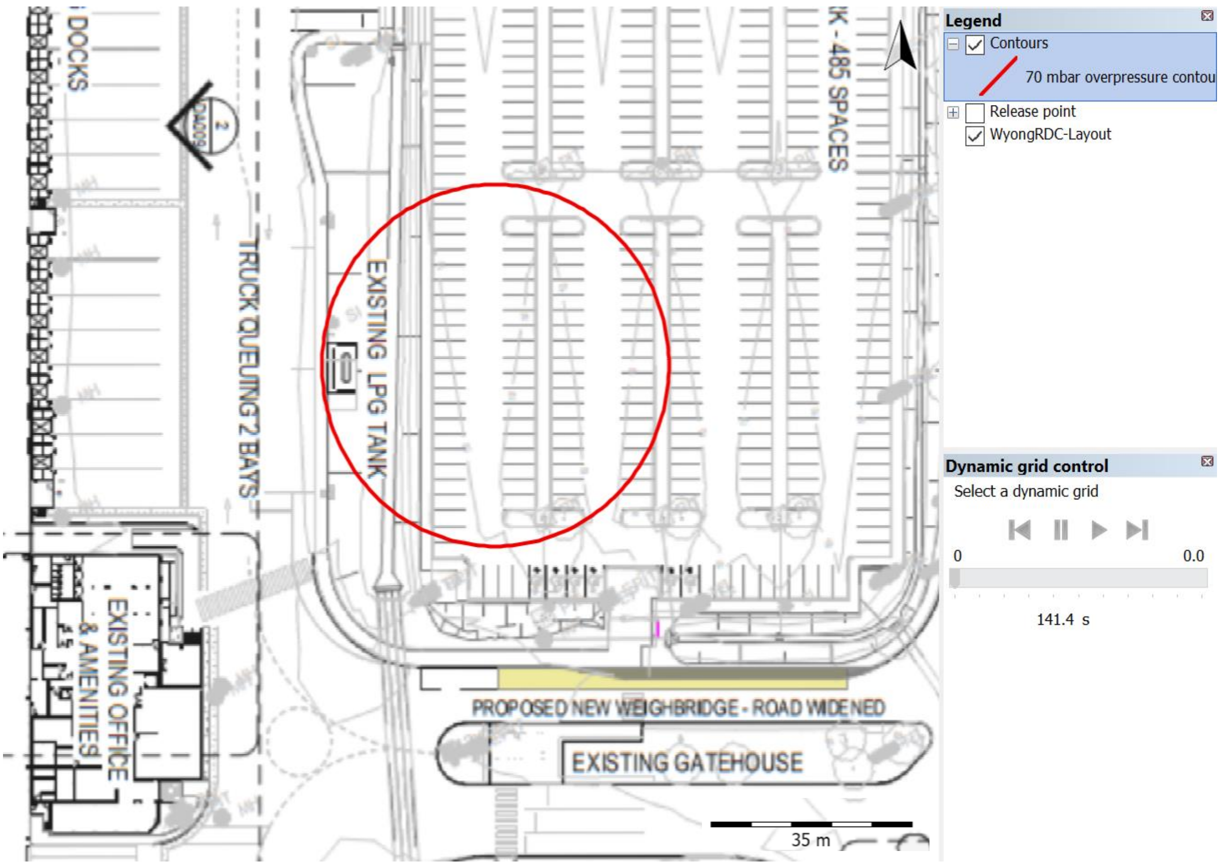

Figure 5-6: LPG Release Explosion Impact Contours

5.8 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Delivery Tanker and BLEVE

As discussed in **Section 4.17,** there is the potential for a release of LPG from a delivery tank which if ignited could result in a jet fire. If the jet fire impinged the delivery tanker the incident could escalate to a BLEVE. A detailed analysis has been performed in **Appendix B10** with the results summarised in **Table 5-8**.

Table 5-8: Overpressure Impacts from an LPG Tanker BLEVE

Overpressure (kPa)	Distance (m)
70	14
35	26
21	41
14	58
7	104

The overpressure contours from the BLEVE have been shown in **Figure 5-7**. As can be seen, neither overpressure contours at 7 kPa and 14 kPa extend over the site boundary; hence, there is no potential for a fatality to occur offsite and for incident propagation. Therefore, this incident has not been carried forward for further analysis.

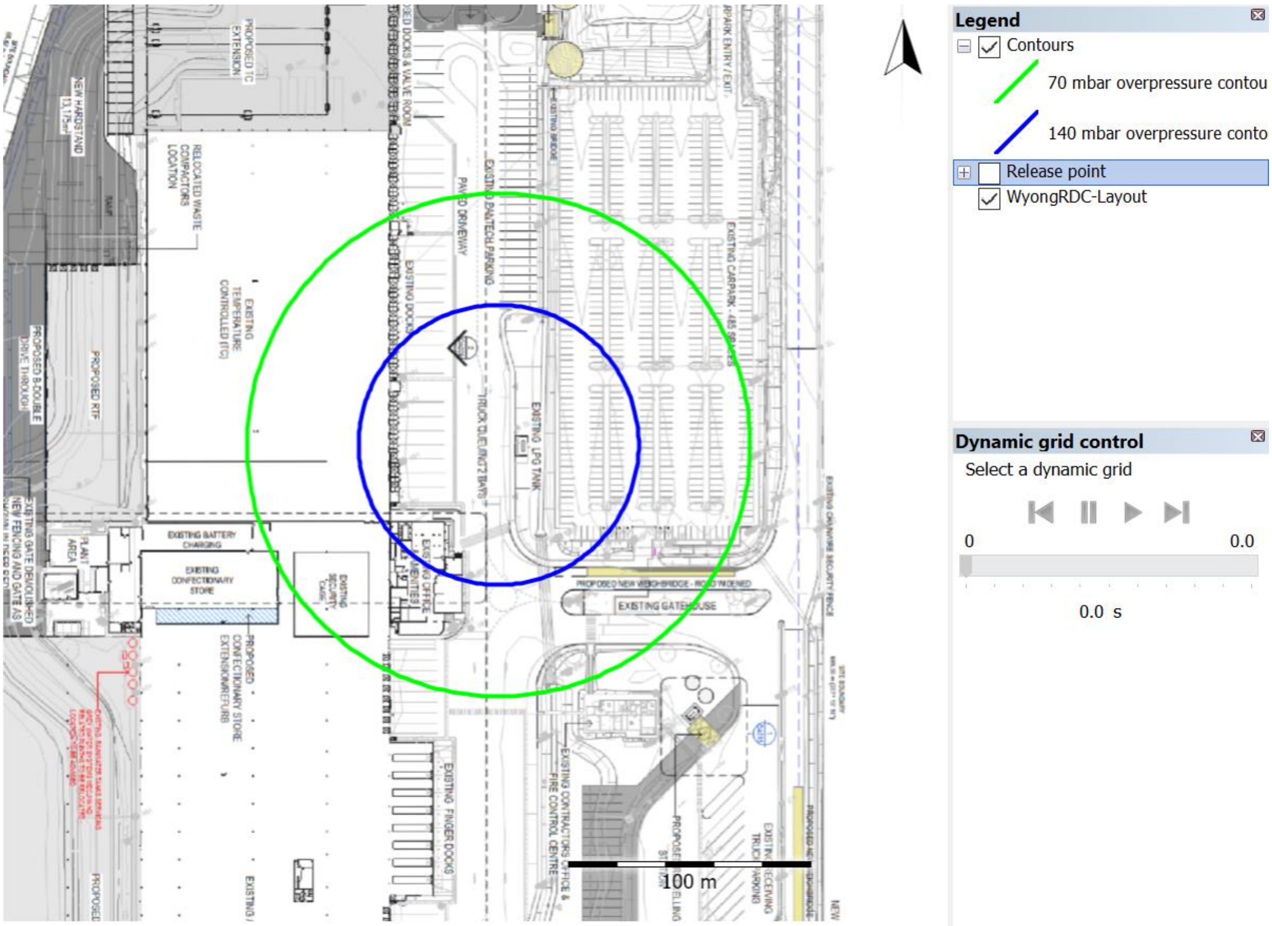

Figure 5-7: LPG Tanker BLEVE Impact Contours

5.9 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Tank And BLEVE

As discussed in **Section 4.18,** there is the potential for a release of LPG from a delivery tank which if ignited could result in a jet fire. If the jet fire impinged the LPG tank the incident could escalate to a BLEVE. A detailed analysis has been performed in **Appendix B11** with the results summarised in **Table 5-9**.

Table 5-9: Overpressure Impacts from an LPG Tank BLEVE

Overpressure (kPa)	Distance (m)
70	8
35	16
21	25
14	35
7	63

The overpressure contours from the BLEVE have been shown in **Figure 5-8**. As can be seen, neither overpressure contours at 7 kPa and 14 kPa do not extend over the site boundary; hence, there is no potential for a fatality to occur offsite and for incident propagation. Therefore, this incident has not been carried forward for further analysis.

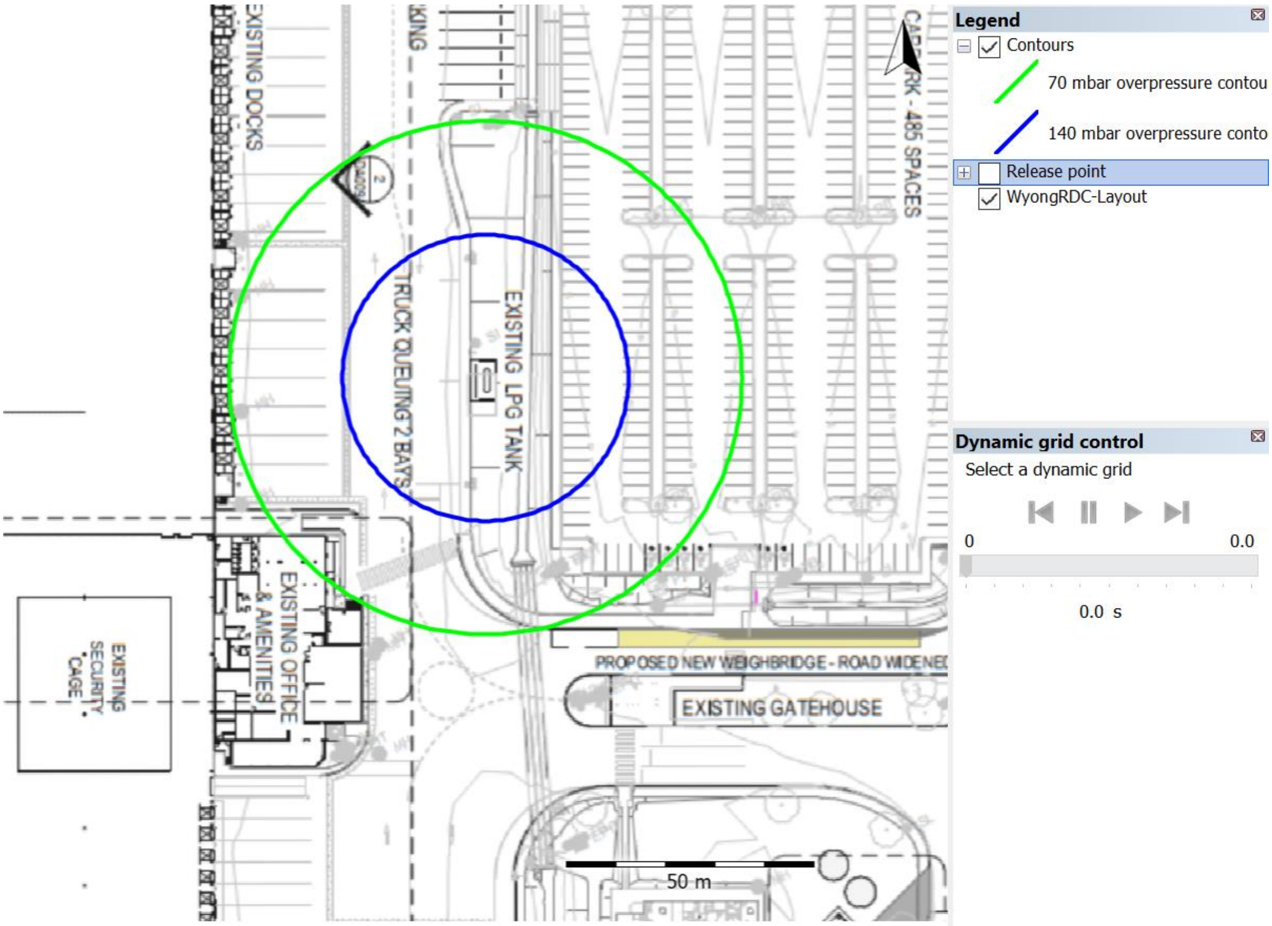

Figure 5-8: LPG Tank BLEVE Impact Contours

6.0 Frequency Analysis

6.1 Incidents Carried Forward for Frequency Analysis

The following item has been carried forwards for frequency analysis;

- Full warehouse fire and radiant heat.
- Full warehouse fire and toxic smoke emission.

This incident has been assessed in the following section.

6.2 Probability of Failure on Demand

The failure rates for each component identified in the safety systems which protect against the scenarios in the following sections were sourced from 3rd party databases such as; OREDA, Exida, UK Health and Safety Executive (HSE). A summary of the failure rate information has been conducted in **Appendix C**. Also included in this appendix are the calculations for the probability of failure on demand (PFD) for each component which is estimated using **Equation 7-1**.

$$PFD = \frac{1}{2}\lambda_{du}t$$

Equation 7-1

Where:

- λ_{du} = dangerous undetected failures of a component
- t = 1/number of test intervals per annum

6.3 Full Warehouse Fire Frequency and Risk Assessment

The frequency of a full warehouse fire at the site can be estimated from a number of sources (e.g. general warehouse fire frequencies or the summation of individual fire frequencies for each of the initiating fire events). As this is a preliminary hazard analysis, the fire frequency has been selected from general fire frequency data.

A detailed fire frequency analysis has been conducted in **Appendix C**. The results of this analysis indicate that an initiating fire frequency would be in the order of 1×10^{-3} p.a.

It is noted that the site is fitted with multiple automatic sprinkler systems that will initiate on fire detection, controlling the fire and preventing the fire growth to a full warehouse fire. The Centre for Chemical Process Safety (CCPS) provides failure rate data for water fire protection systems including all components (pump, distribution system, nozzles, seals, piping, controls and base plate) of 9.66 per 10^6 hours (Ref. [18]). The hourly failure rate is converted to failures per annum by:

Failures per Annum = Failures per hour x 8760 hours per year

Failures per Annum = 9.66×10^6 x 8760 = 0.085

The system will only operate when a fire is detected; hence, the system operates in demand mode. The protection system will be tested monthly totalling 12 tests per annum. The probability of failure on demand (PFD) is estimated using:

$$PFD = \frac{1}{2}\lambda_{du}\left(\frac{1}{t}\right)$$

Where:

λ_{du} = dangerous undetected failures of a component

t = 1/number of test intervals per annum

PFD = 0.5 (0.085) (1/12) = 0.00353

Hence, the frequency of a full fire within the warehouse is the frequency of an initiating fire x the probability of fail on demand (PFD) of the automatic fire fighting system as shown in **Figure 6-1**.

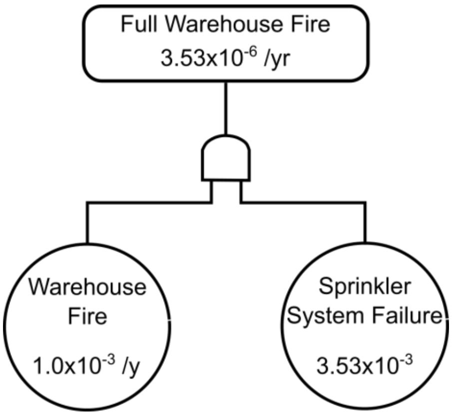

Figure 6-1: Full Warehouse Fire Fault Tree

Conservatively assuming a 100% chance of fatality at the site boundary for a person exposed to radiant heat from a full warehouse fire, the probability of fatality at the site boundary becomes 3.53×10^{-6} x 1 = 3.53×10^{-6} chances of fatality per year or 3.53 chances of a fatality in a million per year (pmpy).

6.4 Full Warehouse Fire and Toxic Smoke Emission Frequency and Risk Assessment

The toxic smoke emission (or toxic bi-products of combustion) is based on the initiating event which is the formation of a full warehouse fire. Therefore, the frequency of the toxic smoke emission is the same as that of the full warehouse which was identified to be 3.53×10^{-6} p.a.

For conservatism, it has been assumed exposure to the smoke will result in an fatality at the site boundary; therefore, the fatality risk of exposure to the toxic smoke becomes 3.53×10^{-6} x 1 = 3.53 chances pmpy.

6.5 Total Fatality Risk

Provided in **Table 6-1** is a summary of the incidents which may result in a fatality at the site boundary. The total fatality risk at the site boundary was calculated to be 7.06 chances per million per year (pmpy)

Table 6-1: Total Fatality Risk

Incident	Fatality Risk
Full warehouse fire	3.53×10^{-6}
Smoke emission	3.53×10^{-6}
Total	**7.06×10^{-6}**

6.6 Comparison Against Risk Criteria

The NSW Department of Planning and Environment has issued a guideline on the acceptable risk criteria (Ref. [2]). The acceptable risk criteria published in the guideline relates to injury, fatality and property damage. The values in the guideline present the maximum levels of risk that are permissible at the land use under assessment.

The adjacent land uses are classified as an industrial site as it is restricted access and only industrial operations are permitted to occur in this area. For industrial facilities, the maximum permissible fatality risk is 50 pmpy. The assessed highest fatality risk is 7.06 pmpy at the closest site boundary (western and northern boundary); hence, the highest risk is within the permissible criteria and therefore all other risk points beyond the boundary would be within the acceptable criteria.

Based on the estimated injury risk, conducted in the analysis above, the risks associated with injury and nuisances at the closest residential area are not considered to be exceeded.

6.7 Cumulative Assessment

A review of the surrounding area indicates there are several warehouses within the vicinity; however, an understanding of the area indicates there are no warehouses storing substantial quantities of DGs within the area; hence, cumulative risks are not considered to be a risk at this stage.

7.0 Conclusion and Recommendations

7.1 Conclusions

A hazard identification table was developed for the warehouse facility to identify potential hazards that may be present at the site as a result of operations or storage of materials. Based on the identified hazards, scenarios were postulated that may result in an incident with a potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. Scenarios not eliminated were then carried forward for consequence analysis.

Incidents carried forward for consequence analysis were assessed in detail to estimate the impact distances. Impact distances were developed into scenario contours and overlaid onto the site layout diagram to determine if an offsite impact would occur. The consequence analysis showed that one of the scenarios (full warehouse fire) would impact over the site boundary and into the adjacent land use; hence, this incident was carried forward for frequency analysis and risk assessment.

The frequency analysis and risk assessment showed that the full warehouse fire would have a fatality risk of 7.06 chances per million per year (pmpy) at the site boundary, with lesser risk at further distances from the boundary. HIPAP No. 4 (Ref. [2]) publishes acceptable risk criteria at the site boundary of 50 pmpy (for industrial sites). Therefore, the probability of a fatality from a full warehouse fire at the site boundary is within the acceptable risk criteria.

In addition, it was found that no incidents would result in impacts to adjacent structures. It is noted that for a full warehouse fire, due to the fire size there will be considerable smoke emitted which would obscure the flame surface reducing the average surface emissive power (SEP) and subsequently it would not exceed 23 kW/m^2. In addition, the distance to the closest building is 50 m which would allow attenuation of radiant heat from of luminous spots and would not result in sustained radiant heat such that propagation to adjacent facilities would occur.

Based on the analysis conducted, it is concluded that the risks at the site boundary are not considered to exceed the acceptable risk criteria; hence, the facility would only be classified as potentially hazardous and would be permitted within the current land zoning for the site.

7.2 Recommendations

Notwithstanding the conclusions following the analysis of the facility, the following recommendations have been made:

- Spill kits shall be provided in all areas where DGs are stored to facilitate clean up response.
- The use of spill kits shall be incorporated into the site Emergency Response Plan (ERP).

8.0 References

[1] NSW Department of Planning and Environment, "Applying SEPP33 – Hazardous and Offensive Developments," NSW Department of Planning and Environment, Sydney, 2011.

[2] Department of Planning, "Hazardous Industry Planning Advisory Paper No. 4 - Risk Criteria for Land Use Safety Planning," Department of Planning, Sydney, 2011.

[3] Department of Planning, "Hazardous Industry Planning Advisory Paper No. 6 - Guidelines for Hazard Analysis," Department of Planning, Sydney, 2011.

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[5] Standards Australia, "AS/NZS 3833:2007 - Storage and Handling of Mixed Classes of Dangerous Goods, in Packages and Intermediate Bulk Containers," Standards Australia, Sydney, 2007.

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[7] Standards Australia, AS/NZS 60079.10.1:2009 - Explosive Atmospheres Part 10.1: Classification of Areas, Explosive Gas Atmospheres, Sydney: Standards Association of Australia, 2009.

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[19] Standards Australia, “AS/NZS 5149:2016 - Refrigerating systems and heat pumps - Safety and environmental requirements Definitions, classification and selection criteria,” Standards Australia, Sydney, 2016.

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Appendix A

Hazard Identification Table

A1. Hazard Identification Table

ID	Area/ Operation	Hazard Cause	Hazard Consequence	Safeguards
1	Flammable Gas Cylinders (Ethylene, Acetylene)	• Loss of containment of ethylene or acetylene gas	• Fire and / or explosion resulting in potential injuries onsite and potentially offsite	• Small ethylene cylinders (i.e. <50 L) • Valve guards on cylinders • Pressure tested cylinders • Minor storage complying with AS 4332-2004 (Ref. [13]). • Low gas flow rate used in ethylene ripening (i.e. maximum concentration of 10 ppm)
2	Argon (Class 2.2) gas release	• Loss of containment of argon gas	• Release of Class 2.2 gases • Oxygen depletion	• Valve guards on cylinders • Pressure tested cylinders • Minor storage complying with AS 4332-2004 (Ref. [13]).
3	Oxygen (Class 2.2 (5.1)) gas release	• Loss of containment of oxygen gas during a fire	• Exacerbation of an existing fire, resulting in potential injuries onsite and potentially offsite	• Valve guards on cylinders • Pressure tested cylinders • Minor storage complying with AS 4332-2004 (Ref. [13]), including segregation from flammable substances. • Automatic fire protection system
4	Warehouse	• Dropped pallet • Damaged packaging (receipt or during storage) • Deterioration of packaging	• Release of Class 2.1, 2.2, 5.1, and 8 to the environment	• Small retail sized packages (< 20 L) • Inspection of packages upon delivery to the site. • Trained forklift operators (including spill response training). • Storage of DGs within AS/NZS 3833:2007 compliant store (Ref. [5])
5		• Heating of Class 2.1 from a general warehouse fire	• Rupture, ignition and explosion/rocketing of cylinder within warehouse spreading fire	• In-rack sprinklers according to AS 2118.1:2017 (Ref. [6]) • Automatic fire protection system • Aerosols stored within a caged area.

ID	Area/ Operation	Hazard Cause	Hazard Consequence	Safeguards
6		• Dropped pallet • Damaged packaging (receipt or during storage) • Deterioration of packaging	• Release of Class 2.2 gases • Oxygen depletion	• Small retail sized packages (< 20 L) • Inspection of packages upon delivery to the site. • Aerosols stored within a caged area.
7	Anhydrous Ammonia (Refrigeration Plant)	• Loss of containment of anhydrous ammonia refrigeration system • Leaking flanges / valves / pipes / pumps • Loss of containment of compressors • Failure of pumps • Loss of containment of heat exchangers / condensers	• Potential for release of toxic ammonia gas • Potential for injuries and/or fatalities (onsite and offsite)	• Ammonia system to comply with AS/NZS 5149 (Ref. [19]) • Gas detection and alarms • Safety interlocks and SCADA system • Emergency Response and Evacuation Plans • Emergency shutdown system • Fire detection and suppression (dilution of ammonia gas with fire water) • Appropriate ventilation system for plant room
8	Anhydrous ammonia (Refrigeration plant)	• Loss of containment of NH_3 above LEL • Presence of ignition sources	• Fire and / or explosion resulting in potential injuries onsite and potentially offsite	• Minor quantity of ammonia stored • Ammonia system to comply with AS/NZS 5149 (Ref. [19]) • HAC in accordance with AS/NZS 60079.10.1:2009 (Ref. [7]) • Exclusion of ignition sources in hazardous areas
9	LPG Tank	• Releases from pipework due to corrosion, flange leaks, hose/pump leaks, weld failure, operator error, maintenance error, mechanical damage (e.g. tanker impact on fill point) etc.	• Minor leak (5 mm hole) • Major leak (50 mm hole) • If ignition then: ○ Flash fire, jet fire, pool fire, VCE or BLEVE (tanker), possible explosion if enters drains, and potentially	• LPG facilities to be designed to comply with AS/NZS 1596:2014 (Ref. [16]) and will be installed by an experienced LPG facility supply company. • Tank and associated pipework/fitting will be pressure tested in accordance with the requirements of the pressure vessels code

ID	Area/ Operation	Hazard Cause	Hazard Consequence	Safeguards
		• Overfilling of tank due to operator error (incorrect tank reading) • Overfilling of tanker due to equipment fault or procedures not followed (e.g. leaving operation unattended). • Hose failure or coupling failure or coupling not properly engaged during transfers due to mechanical damage or undetected wear and tear or operator error. • Drive away with hoses attached.	hazardous heat radiation, direct fire involvement, and/or overpressure/ projectiles. • Potential fire propagation to adjacent sites.	• Ignition source control including earthing to prevent static sparks. • Hoses tested annually as per AS/NZS 1596:2014 and the ADG (Ref. [15]) • Excess flow valves installed in pipework. • Valves to fill point closed until air connected to truck. • Valves shut on breaking of air connection to truck. • All staff including contract drivers will be trained in the specific transfer operations at the site. • Tanker fitted with Emergency Shut Down • Excess flow valve on tanker • Manual shutdown valve • Non-return valve on delivery line • Emergency Shutdown on delivery line • Manual valve on delivery line • Overfill protection device • Fusible link on tanker and vessel
10	Diesel refuelling tank	• Loss of containment of diesel fuel during fuel transfers • Loss of hose connection during fuel transfers • Loss of containment of diesel storage tank • Loss of containment of tanker vehicle • Overfilling of tank	• Release of diesel to the environment	• Storage area to comply with AS 1940-2017 (Ref. [14]) • Storage tank to comply with AS 1692-2006 (Ref. [20]) • Spill containment for delivery vehicles • Self-bunded tank • Vehicle impact protection • Overfill protection
11			• Release of diesel, ignition and pool fire	• Storage area to comply with AS 1940-2017 (Ref. [14]) • Storage tank to comply with AS 1692-2006 (Ref. [20])

ID	Area/ Operation	Hazard Cause	Hazard Consequence	Safeguards
		• Vehicle collision resulting in damage		• Spill containment for delivery vehicles • Self-bunded tank • Vehicle impact protection • Overfill protection • Low ignition probability due to high flash point of diesel (i.e. flash point above ambient conditions)

Appendix B

Consequence Analysis

Appendix B

B1. Incidents Assessed in Detailed Consequence Analysis

The following incidents are assessed for consequence impacts.

- LPG release (from aerosol), ignition and racking fire.
- Full warehouse fire and radiant heat.
- Full warehouse fire and toxic smoke emission.
- LPG release, ignition and pool fire.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire.
- LPG release and ignition causing flash fire or explosion.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG delivery tanker and BLEVE
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG tank and BLEVE.

Each incident has been assessed in the sections below.

B2. Gexcon - Effects

The modelling was prepared using Effects which is proprietary software owned by Gexcon which has been developed based upon the TNO Coloured books and updated based upon CFD modelling tests and physical verification experiments. The software can model a range of incidents including pool fires, flash fires, explosions, jet fires, toxic dispersions, warehouse smoke plumes, etc.

B3. Radiant Heat Physical Impacts

Appendix Figure B-1 provides noteworthy heat radiation values and the corresponding physical effects of an observer exposed to these values (Ref. [2]).

Appendix Figure B-1: Heat Radiation and Associated Physical Impacts

Heat Radiation (kW/m^2)	Impact
35	• Cellulosic material will pilot ignite within one minute's exposure • Significant chance of a fatality for people exposed instantaneously
23	• Likely fatality for extended exposure and chance of a fatality for instantaneous exposure • Spontaneous ignition of wood after long exposure • Unprotected steel will reach thermal stress temperatures which can cause failure • Pressure vessel needs to be relieved or failure would occur
12.6	• Significant chance of a fatality for extended exposure. High chance of injury • Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure • Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure

Heat Radiation (kW/m^2)	Impact
4.7	• Will cause pain in 15-20 seconds and injury after 30 seconds exposure (at least second degree burns will occur)
2.1	• Minimum to cause pain after 1 minute

B4. LPG Release (From Aerosol), Ignition and Racking Fire

The release of LPG from a damaged package could result in a fire if the release ignited. The fire would begin to grow expanding LPG within other aerosols which may rupture, ignite and rocket around the aerosol store. The store is fitted with SMSS and in-rack sprinklers to suppress the fire and cool adjacent packages to minimise the potential for rocketing.

As heat and smoke is generated from the fire, the in-rack sprinklers and the SMSS will activate. Two sprinkler activation scenarios have been assessed:

- A base case scenario whereby the first row of the SMSS activates and controls the spread of a fire.
- A sensitivity scenario whereby the first row of sprinklers fails to activate and the fire is instead controlled by the second row of the SMSS.

The first row of sprinkler has an approximate diameter of 3 m with the second row having an approximate diameter of 9 m. These diameters are used to estimate the flame height and SEP for the fire scenarios. To estimate the flame height and SEP the following information was substituted into the models:

- Equivalent fire diameter: Base – 7 m^2, Sensitivity – 63.6 m^2
- Burning rate – 0.099 $kg/m^2.s$ (the burning rate for LPG, Ref. [21]).

The selection of a LPG burning rate is considered appropriate and conservative as a fire involving aerosols will be composed predominantly of packaging (i.e. plastic wrapping and cardboard) which will be punctuated by rupturing of cans and combustion of the released LPG. The packaging is a solid material that will yield a lower burning rate than selected as it requires an additional phase change prior to combustion reducing the rate at which the product burns.

Furthermore, the analysis is considered incredibly conservative as it assumes a 100% burning area; however, as the subject areas will encompass aisle spaces, there will be no combustible material stored in these locations. Therefore, it is considered the results generated from this analysis would substantially overestimate the radiant heat impacts from the identified scenarios.

The results for flame height and SEP for each scenario are summarised in **Appendix Figure B-2**.

Appendix Figure B-2: Flame Height and SEP for Class 2.1 Sprinkler Controlled Scenarios

Output	Base Case	Sensitivity
Flame Height (m)	10.8	23.2
SEP (kW/m^2)	103.7	60.8

The inputs summarised in **Appendix Figure B-2** were input into Effects with the results for each scenario shown in **Appendix Figure B-3**.

Appendix Figure B-3: Heat Radiation from Class 2.1 Sprinkler Controlled Scenarios

Heat Radiation (kW/m^2)	Distance (m)	
	Base Case	Sensitivity
35	6.0	13.0
23	7.0	16.0
12.6	9.0	22.0
4.7	14.0	34.0

B5. Full Warehouse Fire

A full warehouse fire would consume the combustible load stored within the warehouse which covers an approximate area of 18,200 m^2. A burning rate of 0.054 kg/m^2.s has been selected which is considered conservative as the majority of product stored within the warehouse is non-DG and this burning rate reflects that of relatively flammable material.

The input parameters entered into the model have been shown in **Appendix Figure B-4**.

Parameters	
Inputs	
Process Conditions	
Chemical name	Brent Crude Sample (Sample mixtures)
Calculation Method	
Type of pool fire calculation	Two zone model Rew & Hulbert
Type of pool fire source	Instantaneous
Soot definition	Calculate/Default
Source Definition	
Total mass released (kg)	1E05
Temperature of the pool (°C)	25
Process Dimensions	
Type of pool shape (pool fire)	Polygon
Non burning area within pool (m2)	0
Height of the confined pool above ground level (m)	0
Include shielding at bottomside flame	No
Meteo Definition	
Wind speed at 10 m height (m/s)	2
Predefined wind direction	NE
Environment	
Ambient temperature (°C)	25
Ambient pressure (bar)	1.0151
Ambient relative humidity (%)	60
Amount of CO2 in atmosphere (-)	0.0004

Appendix Figure B-4: Full Warehouse Fire Input File

The results for flame height and SEP for each scenario are summarised in **Appendix Table B-1**.

Appendix Table B-1: Flame Height and SEP for an Full Warehouse Fire

Item	Output
Flame Height (m)	100.6
SEP Sooty Flame (kW/m^2)	25.2

Appendix Table B-2 summarises the radiant heat impact distances calculated for the model.

Appendix Table B-2: Heat Radiation from a Full Warehouse Fire

Heat Radiation (kW/m^2)	Distance (m)	
	North	South
35	64	66

Heat Radiation (kW/m^2)	Distance (m)	
	North	South
23	71	73
12.6	94	102
4.7	155	180

B6. Full Warehouse Fire and Smoke Emission

During the fire, uncombusted toxic products may be present in the smoke plume or toxic bi-products may be generated which will be dispersed in the smoke plume. It is necessary to assess the associated impacts of the smoke plume downwind of the facility as it may have far reaching impacts on the wider community. When assessing the downwind impacts of the fire plume, the main contributors to the dispersion are:

- The fire size (diameter) and energy released as convective heat
- The atmospheric conditions such as wind speed, relative humidity, atmospheric stability and ambient temperature.

These parameters interact to determine the buoyancy of the smoke plume (vertical rise) which is controlled by the convective energy within the smoke plume in addition to the atmospheric conditions. The atmospheric conditions will vary from stable conditions (generally night time) to unstable conditions (high insolation from solar radiation) which results in substantial vertical mixing which aids in the dispersion. Contributing to this is the impact of wind speed which will limit the vertical rise of a plume but may exacerbate the downwind impact distance.

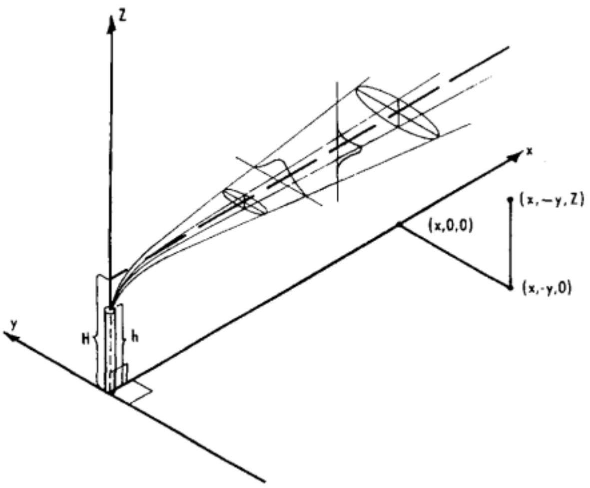
The atmospheric conditions are classified as Pasquill Guifford's Stability categories which are summarised in **Appendix Figure B-5** (Ref. [22]).

Appendix Figure B-5: Pasquill's Stability Categories

Surface wind speed at 10 m height (m/s)	Insolation			Night	
	Strong	Moderate	Slight	Thinly overcast or ≥50% cloud	<50% cloud.
<2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Generally, the most onerous conditions are F conditions which result in stable air masses and typically have inversion characteristics. Inversion characteristics occur when a warm air mass sits above a cold air mass. Typically, hot air will rise due to lower density than the bulk air; however, in an inversion, a warm air mass sits above the cooler denser air; hence, as the warm air rises through the cold mass it hits a 'wall' of warmer air preventing vertical mixing above this point. In a fire scenario, the hot smoke plume will cool as it rises; however, if it encounters an inversion, it will begin to run along this boundary layer preventing vertical mixing and allowing the smoke plume to spread laterally for substantial distances.

A smoke plume is buoyant, and will disperse laterally and vertically as it rises essentially following a Gaussian dispersion as shown in **Appendix Figure B-6** (Ref. [22]).



Appendix Figure B-6: Co-ordinate System for Gas Dispersion

RiskEffects has been used to model a smoke plume arising from the warehouse. The model has been developed based on a Gaussian dispersion model accounting for modifications to the plume drag coefficients required to model a plume dispersion from a warehouse fire.

The model requires several inputs which have been summarised in **Appendix Figure B-7** with the associated value input as part of this modelling exercise. D3 conditions have been used to model the plume dispersion.

Parameters	
Inputs	
Process Conditions	
Phase	Solid
Average molecular formula	Translation for "ParameterValues.C390H850O106Cl046N117S051P135" is missing!
Calculation Method	
NO2 conversion fraction (-)	0.35
Fraction combustion heat radiated (-)	0.35
Fraction of soot (unburned carbon) (-)	0.8
Source Definition	
Total mass released (kg)	1E06
Surface area of the fire (m2)	30500
Environment	
Ambient temperature (°C)	25

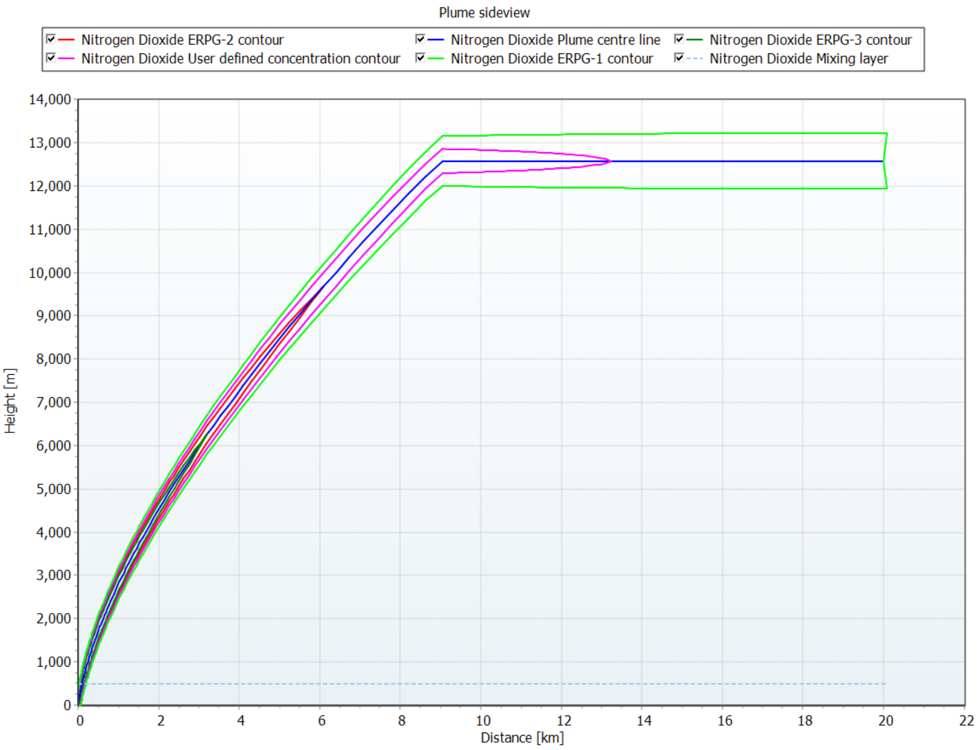
Appendix Figure B-7: Input Data for Plume Gaussian Dispersion

The warehouse was modelled based upon solid product stored within the warehouse and the default settings for solid product within the warehouse was adopted which is based upon typical warehouse configurations within the Netherlands which would be expected to be similar to those expected in Australia. The model then generates the bi-products which may be released from the combustion of the mass which are then individually modelled for each component. Provided in **Appendix Figure B-8** is a summary of the pollutant release rates generated by the model.

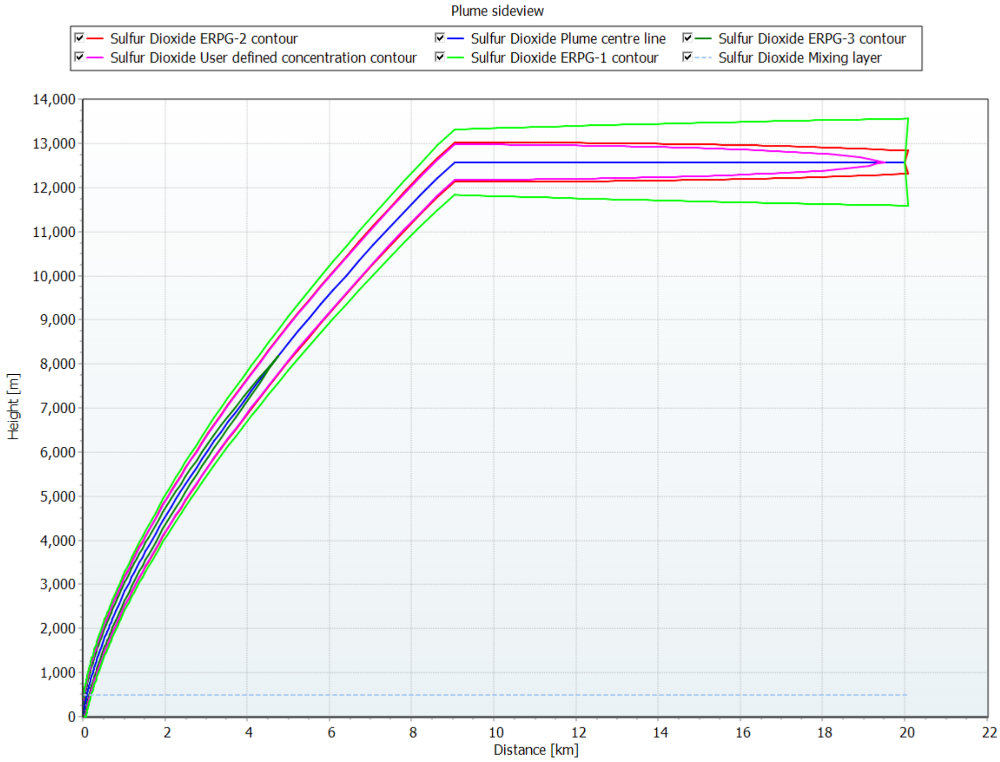
Appendix Figure B-8: Pollutant Release Rates

Material	Release Rate (kg/s)
Nitrogen Dioxide	88.2
Sulphur Dioxide	152.7
Hydrogen Chloride	77.5
Soot (Carbon)	175.2

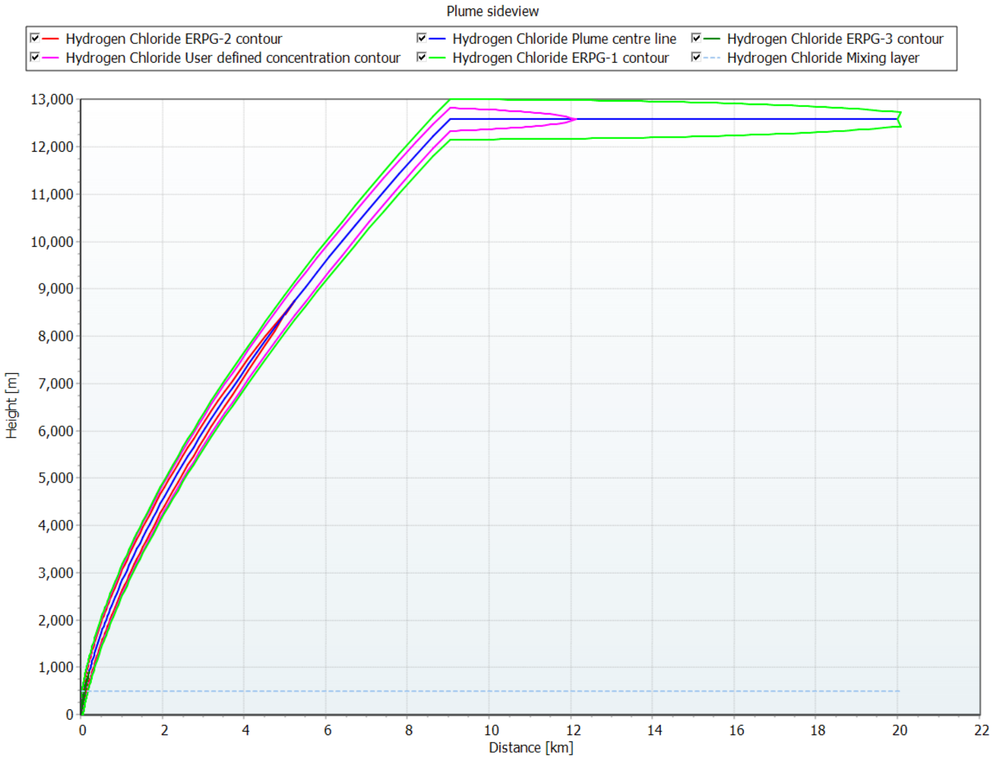
Each of the pollutants were modelled to determine their plume shape and determine whether the plume would puncture through an inversion layer and what the downwind dispersion would look like as the plume cools and settles in the atmosphere. The plume shapes are shown in **Appendix Figure B-9** to **Appendix Figure B-12**.



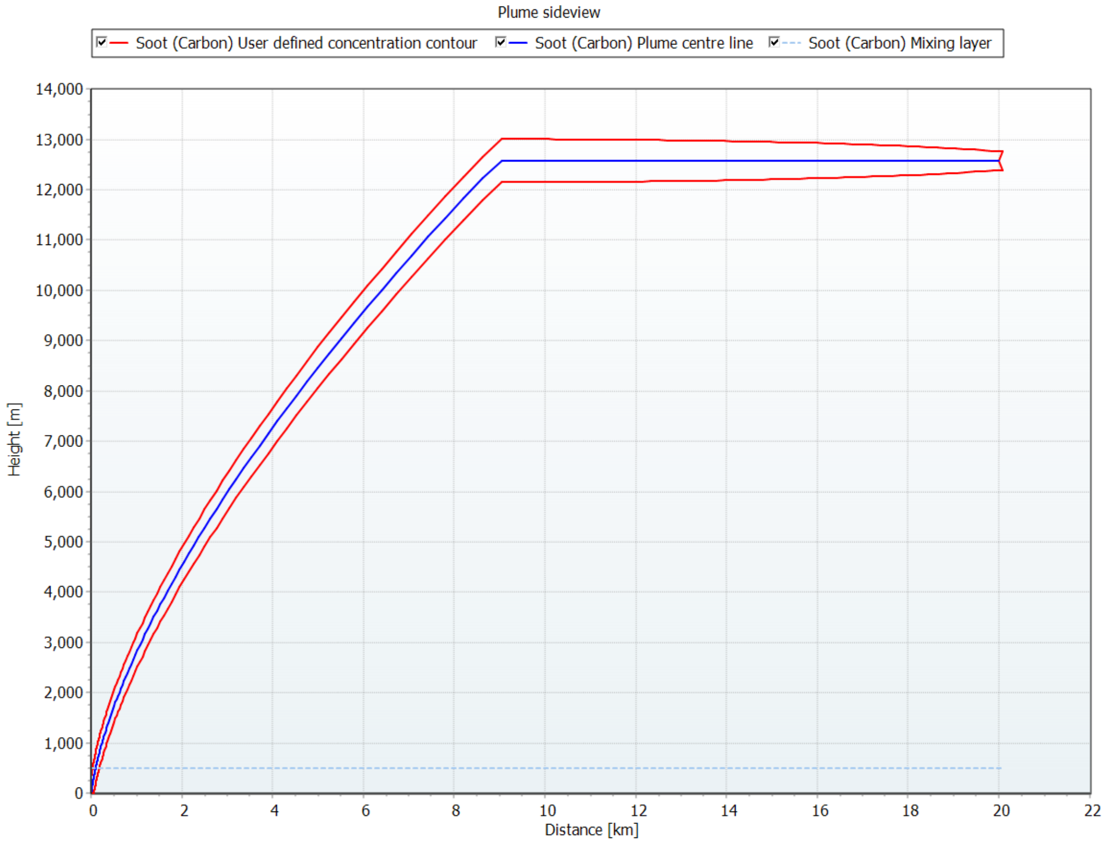
Appendix Figure B-9: Nitrogen Dioxide Downwind Plume Dispersion



Appendix Figure B-10: Sulphur Dioxide Downwind Plume Dispersion



Appendix Figure B-11: Hydrogen Chloride Downwind Plume Dispersion



Appendix Figure B-12: Soot (Carbon) Downwind Plume Dispersion

B7. LPG Release, Ignition and Pool Fire

Following release of LPG, a portion will immediately flash to a gas and disperse downwind and a portion will remain as liquid forming a pool within the vicinity of the release. In the event the pool is ignited it will result in a pool fire which will emit radiant heat which may impact over the site boundary. The release rate from the hose rupture scenario has been used to estimate the pool dimensions and subsequent radiant heat impacts. The input file used to estimate the radiant heat values is provided in **Appendix Figure B-13.**

Parameters	
Inputs	
Process Conditions	
Chemical name	LPG Sample (Sample mixtures)
Calculation Method	
Type of pool fire calculation	Two zone model Rew & Hulbert
Type of pool fire source	Instantaneous
Fraction combustion heat radiated (-)	0.35
Soot definition	Calculate/Default
Source Definition	
Total mass released (kg)	2230.6
Temperature of the pool (°C)	25
Process Dimensions	
Type of pool shape (pool fire)	Circular
Max. pool fire surface area (m2)	441
Height of the confined pool above ground level (m)	0
Include shielding at bottomside flame	No
Meteo Definition	
Wind speed at 10 m height (m/s)	2
Predefined wind direction	W
Environment	
Ambient temperature (°C)	25
Ambient pressure (bar)	1.0151
Ambient relative humidity (%)	60
Amount of CO2 in atmosphere (-)	0.0004

Appendix Figure B-13: LPG Pool Fire Modelling Inputs

The radiant heat impacts calculated from the pool have been summarised in **Appendix Table B-3.**

Appendix Table B-3: Heat Radiation from a LPG Pool Fire

Radiant Heat (kW/m^2)	Distance (m)
35	30
23	37
12.6	50
127	78

B8. LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire

A hose rupture could occur and ignite which would result in a jet fire. The jet fire was modelled using the input parameters in **Appendix Figure B-14**.

Parameters	
Inputs	
Process Conditions	
Chemical name	LPG Sample (Sample mixtures)
Exit temperature (°C)	10.979
Exit pressure (bar)	6.162
Calculation Method	
Fraction of the flame covered by soot (-)	0
Source Definition	
(Calculated) Mass flow rate (kg/s)	13.428
Process Dimensions	
Hole diameter (mm)	50
Hole rounding	Sharp edges
Outflow angle in XZ plane (0°=horizontal; 90°=vertical) (deg)	90
Release height (stack height) (m)	1
Meteo Definition	
Meteorological data	Pasquill
Pasquill stability class	D (Neutral)
Wind speed at 10 m height (m/s)	2
Predefined wind direction	W
Environment	
Ambient temperature (°C)	25
Ambient pressure (bar)	1.0151
Ambient relative humidity (%)	60
Roughness length description	Parkland, bushes; numerous obstacles, x/h < 15.
Amount of CO2 in atmosphere (-)	0.0004

Appendix Figure B-14: Jet Fire Modelling Inputs

The model calculated a jet flame length of 34 m. The radiant heat emitted from the flame is shown in **Appendix Table B-4**.

Appendix Table B-4: Heat Radiation from a Jet Fire

Radiant Heat (kW/m^2)	Distance (m)
35	22
23	29
12.6	40
4.7	62

B9. LPG Release and Ignition Causing Flash Fire or Explosion

In the event of a hose failure and release of LPG, if immediate ignition doesn't occur, the release will disperse downwind. If delayed ignition occurs, the cloud will flash or explode depending upon confinement. LPG has been selected for modelling the evaporating pool and subsequent flash fire or explosion results.

Provided in **Appendix Figure B-15** is a summary of the input information substituted into the Gexcon model for the LPG release.

Parameters	
Inputs	
Process Conditions	
Chemical name	LPG Sample (Sample mixtures)
Calculation Method	
Type of heavy gas release	Horizontal Jet release
Source Definition	
Mass flow rate of the source (kg/s)	13.428
Duration of the release (s)	166
Initial liquid mass fraction (-)	0
Diameter of expanded jet (m)	1
Temperature after release (°C)	-42.25
Process Dimensions	
Height of release (Z-coordinate) (m)	1
Offset X direction (distance) start dispersion (m)	0
Offset Z direction (height) start dispersion (m)	0
Meteo Definition	
Meteorological data	Pasquill
Pasquill stability class	D (Neutral)
Wind speed at 10 m height (m/s)	2
Predefined wind direction	W
Environment	
Ambient temperature (°C)	25
Ambient pressure (bar)	1.0151
Ambient relative humidity (%)	60
Roughness length description	Parkland, bushes; numerous obstacles, x/h < 15.

Appendix Figure B-15: LPG Flash Fire or Explosion Modelling Inputs

The representative evaporation rate and evaporated mass from the pool surface has been provided in **Appendix Figure B-16.**

Appendix Table B-5: Model Outputs for a LPG Release

Item	Output
Evaporation rate (kg/s)	5.7
Flammable mass (kg)	392
Cloud downwind distance to LFL	49.2
Cloud width to LFL	60.2

Appendix Table B-6 summarises the overpressure results from a vapour cloud explosion. The explosion was modelled using a medium deflagration (curve number 5) and 3% of the flammable cloud involved in the explosion.

Appendix Table B-6: Overpressure from an LPG Release Explosion

Heat Radiation (kW/m^2)	Distance (m)
70	Not observed
35	Not observed
21	Not observed
14	Not Observed
7	57

B10. LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Delivery Tanker and BLEVE

In the event that a jet fire impinges upon the delivery tanker the liquid will absorb the heat from the impact point and begin boiling which will be vented from the pressure relief valves on the tank. As the liquid level decreases it will fall below the impingement point and heat will not be removed allowing for the metal to heat up directly. As the metal continues to heat it will become less rigid ultimately to the point where it is unable to contain the pressure of the LPG rupturing as a BLEVE.

It is noted that it's physically impossible to have a BLEVE and a 100% full tank; however, the DPIE has indicated a preference for modelling BLEVEs with 100% tank volume; hence, the BLEVE has been modelled as a 100% full 20 tonne tanker (36.4 m^3 using a density of 550 kg/m^3). The input parameters for the BLEVE modelling are shown in **Appendix Figure B-16.**

Parameters	
Inputs	
Process Conditions	
Chemical name	LPG Sample (Sample mixtures)
Initial temperature in vessel (°C)	25
Burst pressure vessel (bar)	26.5
Process Dimensions	
Vessel volume (m3)	36.4
Filling degree (%)	100
Environment	
Ambient temperature (°C)	25
Ambient pressure (bar)	1.0151

Appendix Figure B-16: LPG Tanker BLEVE Input Parameters

The overpressure impacts calculated from the model have been summarised in **Appendix Table B-7**

Appendix Table B-7: Overpressure from an LPG Tanker BLEVE

Overpressure (kPa)	Distance (m)
70	14
35	26
21	41
14	58
7	104

B11. LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Tank And BLEVE

Similar to the LPG tanker BLEVE, there is the potential for impingement on the LPG tanks themselves which could escalate as a BLEVE. These have been modelled at 100% full for the purposes of this exercise.

The input parameters for the BLEVE modelling are shown in **Appendix Figure B-17**.

Parameters	
Inputs	
Process Conditions	
Chemical name	LPG Sample (Sample mixtures)
Initial temperature in vessel (°C)	25
Burst pressure vessel (bar)	26.5
Process Dimensions	
Vessel volume (m3)	4.5
Filling degree (%)	100
Environment	
Ambient temperature (°C)	25
Ambient pressure (bar)	1.0151

Appendix Figure B-17: LPG Tank BLEVE Input Parameters

The overpressure impacts calculated from the model have been summarised in **Appendix Table B-8.**

Appendix Table B-8: Overpressure from an LPG Tank BLEVE

Overpressure (kPa)	Distance (m)
70	7
35	13
21	20
14	29
7	52

Appendix C

Warehouse Fire Frequency Estimation

C1. Estimation of the Frequency of a Full Warehouse Fire

A review of readily available warehouse fire frequency information was conducted and a number of direct sources were identified. These were:

- Health and Safety Executive (HSE) in the United Kingdom [Hymes & Flynn, UKAEA - SRD/HSE R578, 2002] – this document lists the major warehouse fire frequency to be 2.5×10^{-3} p.a.;
- Baldwin, Accident Analysis and Prevention (Vol.6) – indicates a serious fire frequency in warehouses to be in the order of 1×10^{-3} p.a.;
- Environmental Impact Assessment Report for the Commission of Inquiry into Proposed Manufacturing Plant by WR Grace Australia Ltd., Kurnell, Sydney, October 1987 – indicates a fire frequency of 4.6×10^{-3} per warehouse year; and
- VROM 2005, Guidelines for quantitative risk assessment CPR 18E (Purple Book), Publication Series on Dangerous Substances (PGS 3), The Netherlands. – 4×10^{-4} p.a.

It is noted that the mix of overseas data and local data (albeit some is dated) correlates to indicate a fire frequency in warehouses to be in the order of 1×10^{-3} to 4×10^{-4}. The data presented in the reports reviewed was for general warehouses, where stringent controls for spill and ignition sources (such as flame and explosion proof fittings, bunding, smoking and naked flame controls, isolation of power supplied on warehouse closure, etc.) were not part of the warehouse hazard controls. Hence, for a DG warehouse, containing specific ignition and fire control systems, it would be expected that a major fire would occur with a lesser frequency than that of general warehouses. Notwithstanding this, to ensure a conservative assessment has been provided within the study, the estimated initiating fire frequency for the facility has been estimated as 1×10^{-3} p.a. (i.e. the upper end of the range).

Selected Initiating Fire Frequency = 1×10^{-3} p.a.