



Hazardous Area Classification

29 Sarah Andrews Close, Erskine Park, NSW

Hazardous Area Classification

29 Sarah Andrews Close, Erskine Park, NSW

Woolworths

Prepared by

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Woolworths

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Executive Summary

Background

Woolworths Ltd (Woolworths) currently operates a warehouse located in Erskine Park, NSW which will store a range of goods including some materials classified as Dangerous Goods (DGs). As DGs are stored the facility is subject to the Work Health Safety (WHS) Regulation (Ref. [1]) which requires the risks associated with the storage and handling of DGs to be minimised to ensure safety for personnel working within the warehouse.

AS/NZS 3000:2018 (Ref. [2]) and the Work Health and Safety Regulation (WHS, Ref. [1]) require areas where a flammable atmosphere could occur to be assessed and equipment installed within the area to comply with AS/NZS 60079.14:2022 (Ref. [3]) to minimise potential for ignition.

To ensure electrical equipment present in the Dangerous Goods (DG) stores and the surrounding area comply with AS/NZS 3000:2018 (Ref. [2]), WHS Regulation (Ref. [1]) and AS/NZS 60079.14:2022 (Ref. [3]), it is necessary to prepare a Hazardous Area Classification (HAC) according to AS/NZS 60079.10.1:2022 (Ref. [4]) to identify the extent of the hazardous zones around the storages.

Woolworths has commissioned Riskcon Engineering Pty Ltd (Riskcon) to review the DG stores to identify the extent of the hazardous zones and to assist in the selection of electrical equipment in these locations. This document is Riskcon's HAC of the DG store.

Conclusions

The Woolworths EPDC site at 29 Sarah Andrews Close, Erskine Park NSW was reviewed to determine the hazardous areas associated with storages and operations occurring at the site as part of ongoing risk assessment as required by the WHS Regulation. Based on the assessment, no hazardous zones were identified.

Recommendations

No recommendations have been made as part of this assessment.

Table of Contents

Executive Summary	i
1.0 Introduction	1
1.1 Background	1
1.2 Objectives	1
1.3 Scope of Work	1
2.0 Methodology	2
3.0 Site Description	3
3.1 Site Location	3
3.2 Adjacent Land Uses	3
3.3 Site Description	4
3.4 Quantities of Dangerous Goods Stored and Handled	4
3.5 Aggregate Quantity Ratio	4
4.0 Hazardous Area Classification	8
4.1 Introduction	8
4.2 Flammable Gases (Aerosols)	8
4.2.1 Source of Release	8
4.2.2 Ventilation	8
4.2.3 Grade and Release Rate	8
4.2.3.1 Grade	8
4.2.3.2 Release	8
4.2.4 Dilution	9
4.2.5 Zone Extent	10
5.0 Equipment Grouping	12
5.1 Gas Group	12
5.2 Temperature Class	13
5.3 Equipment Protection Level	13
5.4 Equipment Type	13
5.5 Certification	15
5.6 Hazardous Area Classification Table and Drawings	15
6.0 Conclusions and Recommendations	17
6.1 Conclusions	17
6.2 Recommendations	17
7.0 References	18
Appendix A Evaporation Model and Steady State Concentration	19
A1. Pool Size Model	20

List of Figures

Figure 3-1: Site Location (source Google Maps)	3
Figure 3-2: Site Layout	6
Figure 3-3: Proposed Aerosol Store	7
Figure 4-1: Degree of Dilution Aerosol Release	10
Figure 4-2: Zones for Grade of Release and Effectiveness of Ventilation	11

List of Tables

Table 3-1: Maximum Classes and Quantities of Dangerous Goods Stored	4
Table 3-2: Major Hazard Facility Thresholds	5
Table 4-1: LPG Explosive and Density Limits	9
Table 4-2: Aerosol Release Characteristics	11
Table 4-3: Aerosol Release Hazardous Area	11
Table 5-1: Gas Data	12
Table 5-2: Gas Groupings Summary	12
Table 5-3: Permitted Equipment Groups, from AS/NZS 60079.14:2022	12
Table 5-4: Temperature Classification, from AS/NZS 60079.14:2022	13
Table 5-5: Temperature Class Summary	13
Table 5-6: Equipment Protection Levels based on Zones, from AS/NZS 60079.14:2022	13
Table 5-7: Protection Codes for EPL Ga	13
Table 5-8: Protection Codes for EPL Gb	14
Table 5-9: Protection Codes for EPL Gc	15
Table 5-10: Hazardous Area Classification Table	16

Abbreviations

Abbreviation	Description
CBD	Central Business District
DG	Dangerous Goods
EPL	Equipment Protection Level
HAC	Hazardous Area Classification
LEL	Lower Explosive Limit
MESG	Maximum Experimental Safe Gap
NE	Negligible Extent
NH	Non Hazardous
UEL	Upper Explosive Limit
WHS	Work Health and Safety

1.0 Introduction

1.1 Background

Woolworths Ltd (Woolworths) currently operates a warehouse located in Erskine Park, NSW which will store a range of goods including some materials classified as Dangerous Goods (DGs). As DGs are stored the facility is subject to the Work Health Safety (WHS) Regulation (Ref. [1]) which requires the risks associated with the storage and handling of DGs to be minimised to ensure safety for personnel working within the warehouse.

AS/NZS 3000:2018 (Ref. [2]) and the Work Health and Safety Regulation (WHS, Ref. [1]) require areas where a flammable atmosphere could occur to be assessed and equipment installed within the area to comply with AS/NZS 60079.14:2022 (Ref. [3]) to minimise potential for ignition.

To ensure electrical equipment present in the Dangerous Goods (DG) stores and the surrounding area comply with AS/NZS 3000:2018 (Ref. [2]), WHS Regulation (Ref. [1]) and AS/NZS 60079.14:2022 (Ref. [3]), it is necessary to prepare a Hazardous Area Classification (HAC) according to AS/NZS 60079.10.1:2022 (Ref. [4]) to identify the extent of the hazardous zones around the storages.

Woolworths has commissioned Riskcon Engineering Pty Ltd (Riskcon) to review the DG stores to identify the extent of the hazardous zones and to assist in the selection of electrical equipment in these locations. This document is Riskcon's HAC of the DG store.

1.2 Objectives

The objective of the HAC is to determine the hazardous areas within the DG store(s) at the Woolworths site located at 29 Sarah Andrews Close, Erskine Park NSW in accordance with AS/NZS 60079.10.1:2022 (Ref. [4]). Included in the hazardous zoning will be details of the equipment requirements and specifications for use within any hazardous area to achieve compliance with AS/NZS 60079.14:2022 (Ref. [3]).

1.3 Scope of Work

The scope of work is to prepare a HAC for the proposed warehouse to be located at the Woolworths site located at 29 Sarah Andrews Close, Erskine Park NSW. The assessment does not include any other Woolworths sites nor additional work which may be identified in the course of the assessment.

2.0 Methodology

This document will utilise the following standards:

- AS/NZS 60079.10.1:2022: Explosive Atmospheres, Classification of Areas – Explosive Gas Atmospheres (Ref. [4]).
- AS/NZS 60079.14:2022: Explosive Atmospheres, Electrical Installations Design, Selection and Erection (Ref. [3]).

This Hazardous Area Classification examines the requirements from AS/NZS 60079.10.1:2022 in specifying hazardous areas. The use of the building was examined, including the potential chemicals to be utilised within the building.

The potential sources of release were reviewed to identify the credible release scenarios. These were then reviewed for their ventilation and release characteristics to determine the potential for a hazardous atmosphere to form.

Once the extent of the Hazardous Area has been defined and created, the required equipment certification levels are determined from AS/NZS 60079.14:2022. Determination of the appropriate Equipment Protection Level (EPL), Equipment Group and Temperature Class was applied based on the hazardous chemicals present and the Hazardous Area previously defined.

Following equipment identification, a Hazardous Area Classification Table was developed which defines the minimum standards of equipment required for use within the Hazardous Area.

3.0 Site Description

3.1 Site Location

The Woolworths Erskine Park Distribution Centre (EPDC) is located at 29 Sarah Andrews Close, Erskine Park NSW. The site is approximately 39 km west of the Sydney Central Business District (CBD). **Figure 3-1** shows the location of the site in relation to the CBD.

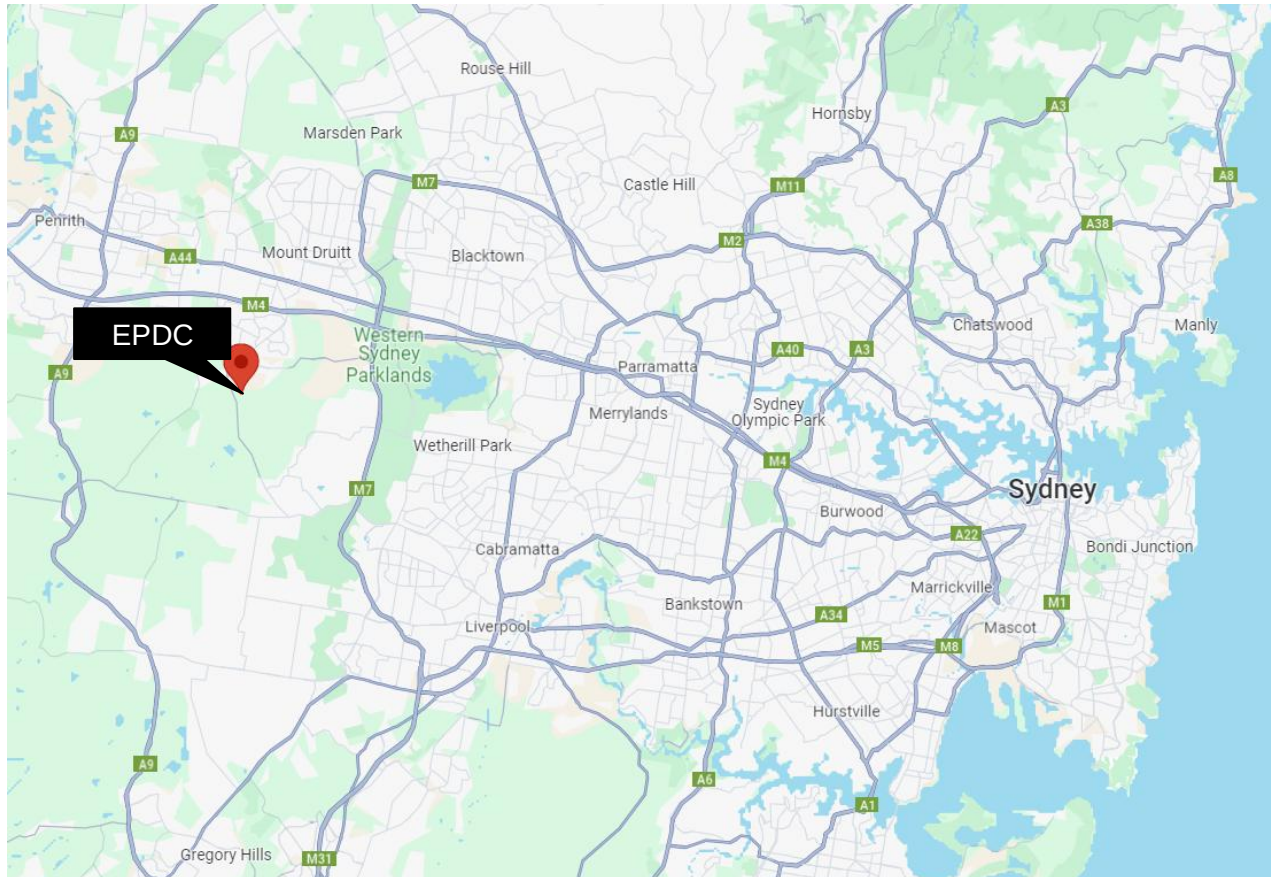


Figure 3-1: Site Location (source Google Maps)

3.2 Adjacent Land Uses

The area is predominantly industrial, with a warehouse development located to the north and to the west. The land to the east is currently vacant and is zoned as IN1 for general industry. The land to the south is also zone as IN1 for general industry but is occupied by a residence located approximately 200 m away from the warehouse.

The site is bounded by the following:

- North – Industrial warehousing, including Linfox and UBEECO Planning Solutions;
- East – Vacant, zoned as IN1 general industrial;
- South – Zoned as IN1 general industrial; and
- West - Industrial warehousing (Toll KCA)

3.3 Site Description

The facility is used to house Woolworths' retail distribution operations, which involves the receipt, storage and handling, and redistribution of a range of products, some of which are classified as DGs. The facility will comprise of the following areas:

- Warehouse – storage of goods in racking, including caged racking for storage of aerosols
- Package handling area – Internal finger dock area and receiving/dispatch docks + staging area
- Gatehouse, Offices and Amenities
- Workshop and Battery Charging Area
- Switch room, Inverter room, Electrical kiosk and Pumphouse.
- On-Grade Car Park

The only dangerous goods stored are Class 2.1 and Class 2.2 aerosols. Aerosols will be stored in the racking within a dedicated caged area. The Aerosol Store is proposed to be located the area that was a cigarette cage (new racking shall be installed to accommodate the aerosols). This racking for the aerosols will be fitted with in-rack fire sprinklers. The site is also fitted with base building specified Storage Mode Sprinkler System (SMSS) sprinklers designed according to FM Global Datasheet concerning sprinklers, which exceeded AS2118.1 at the time. All DG areas are protected by hose reel coverage in addition to hydrant coverage. Additionally, the site is fitted with an automatic penstock valve, which has been designed to close upon activation of the fire alarms on site, providing containment for potentially contaminated fire water.

The warehouse is 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 3833:2024 (Ref. [5]). A layout of the warehouse has been provided in **Figure 3-2**. Additionally, the layout of the aerosol store can be seen in **Figure 3-3**.

3.4 Quantities of Dangerous Goods Stored and Handled

The Woolworths EPDC is not a dedicated DGs storage facility however, a number of DG are stored. The Dangerous Goods stored and handled at the facility are listed in **Table 3-1**.

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

Class	Packing Group (PG)	Proper Chemical Name	Quantity (tonnes)	No. of pallets
2.1	n/a	Aerosols (LPG)	99.4 / 24.85*	514
2.2	n/a	Non-flammable, non-toxic gases (aerosols)	5	24

*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**:

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

Where:

$x, y, \dots$ and n are the dangerous goods present

$q_x, q_y, \dots$ and q_n is the total quantity of dangerous goods $x, y, \dots$ and n present.

$Q_x, Q_y, \dots$ and Q_n is the individual threshold quantity for each dangerous good of $x, y, \dots$ 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. [1]). These are summarised in **Table 3-2**.

Table 3-2: Major Hazard Facility Thresholds

Class	Description	PG	Storage (tonnes)	Threshold (tonnes)
2.1	LPG	n/a	99.4 [^]	200
2.2	Non-flammable, non-toxic gas	n/a	5	Not subject to MHF

[^]Note: Following advice from SafeWork, the net mass of aerosols instead of the LPG component is used in this instance.

A review of the thresholds and the commodities and packing groups listed in **Table 3-1** indicates only Class 2.1 are assessable against the MHF thresholds. Therefore, it is not necessary to calculate an AQR. As shown in **Table 3-2**, the quantity of LPG proposed to be stored is below the MHF threshold; hence, the facility would not be classified as an MHF.

However, the site would exceed 10% of the MHF threshold and therefore notification to SafeWork NSW of a potential MHF would be required.



**PRIMARY
CONNECT**

PRELIMINARY
NOT FOR CONSTRUCTION

[illegible]

**watson
young**

PROJECT: EPDC NEW AEROSOL STORE

TITLE: 29 SARAH ANDREWS CL,
ERSKINE PARK, NSW 2759
SITE PLAN

CLIENT: PRIMARY CONNECT

DATE: MAY, 2024

SCALE: 1 : 1000 @ B1

CHECKED BY: Checker TRUE NORTH PROJECT NORTH

FILE PATH:	C:\Autodesk\Revit\Local 2022\2053_Model_Central_V02_James CL32DR.rvt		
PLOT DATE:	2011/02/04 8:20:00 AM		
JOB NO.	DRAWING NO.	REVISION	

22253 A1100 P1

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6

Figure 3-3: Proposed Aerosol Store

4.0 Hazardous Area Classification

4.1 Introduction

A review of the DGs proposed to be stored indicates the following DGs require assessment:

- Flammable gases (Aerosols)

The storage has been assessed in accordance with AS/NZS 60079.10.1:2022 (Ref. [4]) in the following sections.

4.2 Flammable Gases (Aerosols)

4.2.1 Source of Release

Aerosols stored are assumed to have a volume of <1 L which contain Liquefied Petroleum Gas (LPG) as the propellant. Therefore, the assessment has been conducted based upon LPG for an aerosol can with a volume <1 L.

4.2.2 Ventilation

It is assumed that the warehouse will be naturally ventilated at a rate of approximately 1 air exchange per hour. Therefore, it is considered that this would provide a moderate degree of ventilation. AS/NZS 60079.10.1:2022 under C.3.4 indicates that for outdoor situations the wind velocity for natural ventilation is typically 0.5 m/s. However, to account for any dead zones of air exchanges due to non-ideal conditions, a conservative indoor wind speed of 0.05 m/s is taken.

It is considered that the availability of the ventilation would be fair based upon the established variables.

4.2.3 Grade and Release Rate

4.2.3.1 Grade

Aerosols are enclosed cannisters which are protected by packaging and are unlikely to discharge in normal storage as they are pressure tested once filled ensuring that only products of sound structure are shipped from the manufacturing site. Aerosols may release during storage if damaged (i.e. forklift tyres) or if the valve is depressed by misaligned weight. It is noted that the valve cap would need to be damaged to result in the valve being depressed. Therefore, it is considered unlikely that an aerosol would discharge in normal storage. Therefore, the grade of release would be classified as secondary.

4.2.3.2 Release

A methodology for calculating the mass release from an aerosol can has been provided in **Appendix A**. The following information was input into **Equation A-1** to estimate the mass flow from an aerosol can.

- $C_d = 0.6$ for rough edged hole
- $A = 0.25$ mm diameter hole = $4.9 \times 10^{-8} \text{ m}^2$
- $M = 51$ (LPG: 50/50 mix of propane / butane)
- $P_1 = 0.86$ MPa

- $\gamma = 1.3$
- $R = 8.314 \text{ J/mol.k}$
- $T = 293 \text{ K}$

Calculating for the flow rate of LPG:

$$G_L = 0.6 \times 4.9 \times 10^{-6} \times 0.86 \times 10^6 \left[\left(\frac{51 \times 1.3}{8.314 \times 293} \right) \left(\frac{2 \times 1.3}{1.3 + 1} \right)^{\left(\frac{1.3+1}{1.3-1} \right)} \right]^{0.5} = 7.86 \times 10^{-5} \frac{\text{kg}}{\text{s}}$$

4.2.4 Dilution

The degree of dilution is calculated by determining the volumetric release rate and reading it from **Figure 4-1**. The volumetric release rate is calculated by inputting the following information.

- $W_g = \text{Evaporation Rate} = 1.2 \times 10^{-4} \text{ kg/s}$
- LEL: 0.0155 (From **Table 4-1**)
- Vapour Density: 2.21 kg/m^3 (From **Table 4-1**)

Table 4-1: LPG Explosive and Density Limits

Gas	LEL (%)	UEL (%)	Vapour Density (kg/m^3)
Propane	1.7	10.9	1.91
Butane	1.4	9.3	2.51
50:50 Mixture	1.55	10.1	2.21

Substituting in to calculate the release characteristic:

$$Release = \frac{7.86 \times 10^{-5}}{0.0155 \times 2.21} = 2.00 \times 10^{-3} \text{ m}^3/\text{s}$$

The degree of dilution is then read from **Figure 4-1**. As can be seen, the ventilation is in the high dilution range. Hence, the graphical methodology may be used to determine the extent of the zone.

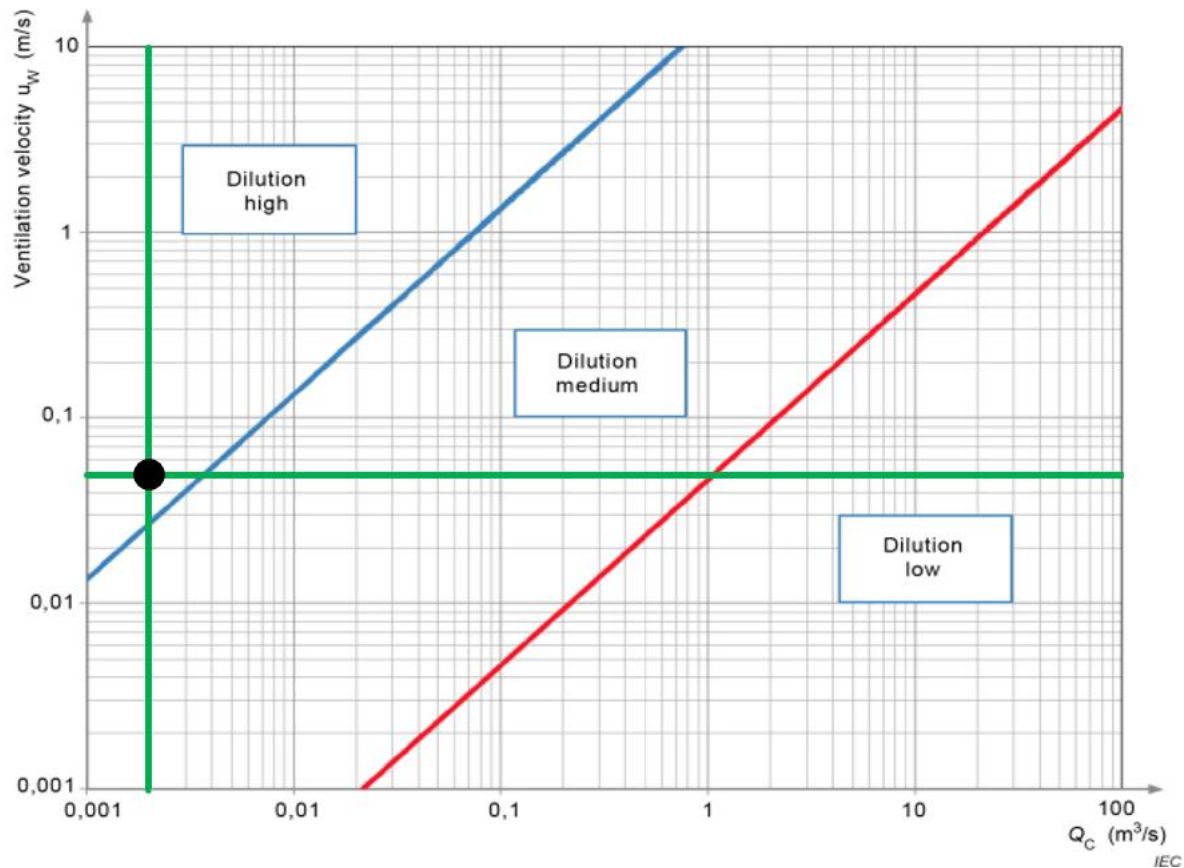


Figure 4-1: Degree of Dilution Aerosol Release

4.2.5 Zone Extent

The extent of the zone can then be calculated by reviewing Table D.1 of AS/NZS 60079.10.1:2022 which has been extracted and provided in **Figure 4-2**. By taking into consideration the grade of release, the dilution, and the availability of the ventilation. Provided in **Table 4-2** is a summary of each of these characteristics.

Grade of release	Effectiveness of Ventilation						
	High Dilution			Medium Dilution			Low Dilution
	Availability of ventilation						
	Good	Fair	Poor	Good	Fair	Poor	Good, fair or poor
Continuous	Non-hazardous (Zone 0 NE) ^a	Zone 2 (Zone 0 NE) ^a	Zone 1 (Zone 0 NE) ^a	Zone 0	Zone 0 + Zone 2 ^c	Zone 0 + Zone 1	Zone 0
Primary	Non-hazardous (Zone 1 NE) ^a	Zone 2 (Zone 1 NE) ^a	Zone 2 (Zone 1 NE) ^a	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or zone 0 ^d
Secondary ^b	Non-hazardous (Zone 2 NE) ^a	Non-hazardous (Zone 2 NE) ^a	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even Zone 0 ^d
^a Zone 0 NE, 1 NE or 2 NE indicates a theoretical zone which would be of negligible extent under normal conditions.							
^b The Zone 2 area created by a secondary grade of release may exceed that attributable to a primary or continuous grade of release; in this case, the greater distance should be taken.							
^c Zone 1 is not needed here. I.e. small Zone 0 is in the area where the release is not controlled by the ventilation and larger Zone 2 for when ventilation fails.							
^d Will be Zone 0 if the ventilation is so weak and the release is such that in practice an explosive gas atmosphere exists virtually continuously (I.e. approaching a 'no ventilation' condition).							
'+' signifies 'surrounded by'.							
Availability of ventilation in naturally ventilated enclosed spaces is commonly not considered as good.							

Figure 4-2: Zones for Grade of Release and Effectiveness of Ventilation

Table 4-2: Aerosol Release Characteristics

Characteristic	Value
Grade of release	Secondary
Dilution	High
Availability	Fair

Reviewing the characteristics of **Table 4-2** indicates the zone is considered to be of Negligible Extent (NE) and thus may be treated as a non-hazardous zone. The zones associated with aerosol products have been summarised in **Table 4-3**.

Table 4-3: Aerosol Release Hazardous Area

Item	Zone Height (m)	Zone Lateral (m)
Aerosol	NE/NH	NE/NH

5.0 Equipment Grouping

5.1 Gas Group

Provided in **Table 5-1** is the relevant gas data for the materials stored.

Table 5-1: Gas Data

Material	Relative Density (to air)	LEL (%)	UEL (%)	MESG (mm)	Temp Class
Propane	1.56	1.7	10.9	0.92	T2
Butane	2.05	1.4	9.3	0.98	T2

*At 60°C.

The Maximum Experimental Safe Gap (MESG) is used to determine the gas grouping of materials and are classified as follows:

- >0.9 mm: IIA
- >0.5 mm and <0.9 mm: IIB
- <0.5 mm: IIC

A review of **Table 5-1** indicates that all chemicals would be gas group IIA. A summary of the gas groups for the flammable materials to be stored are provided in **Table 5-2**

Table 5-2: Gas Groupings Summary

Material	Gas Group
Propane / Butane	IIA

AS/NZS 60079.14:2022 (Ref. [3]) details that electrical equipment shall be selected with appropriate Equipment Groups. Equipment Group is determined through gas subdivision classification, which separates gases into three groups based on potential volatility: IIA, IIB and IIC. IIA are the least volatile gases, including methane, propane and petrol, while IIC are the most volatile gases, including hydrogen and acetylene. **Table 5-3** shows the permitted equipment groups based on gas subdivision.

Table 5-3: Permitted Equipment Groups, from AS/NZS 60079.14:2022

Location Gas/Vapour	Permitted Equipment Group
IIA	II, IIA, IIB, or IIC
IIB	II, IIB, or IIC
IIC	II, or IIC

5.2 Temperature Class

Temperature Class is determined by the expected ignition temperature of the vapour, gas, or dust in °C, and broken down into 6 classifications groups, T1-T6 as shown in **Table 5-4**.

Table 5-4: Temperature Classification, from AS/NZS 60079.14:2022

Temperate Class	Ignition Temperature (°C)	Allowed Equipment Temperature Classes
T1	>450	T1 – T6
T2	>300	T2 – T6
T3	>200	T3 – T6
T4	>135	T4 – T6
T5	>100	T5 – T6
T6	>85	T6

A review of **Table 5-1** indicates the temperature class for Propane/Butane would be T1 and T2, respectively. A summary of the temperature class for each store is provided in **Table 5-5**.

Table 5-5: Temperature Class Summary

Material	Temperature Class
Propane / Butane	T2

5.3 Equipment Protection Level

Table 5-6 has been generated from AS/NZS 60079.14:2022 (Ref. [3]) which describes the individual Equipment Protection Levels required for an applicable zone.

Table 5-6: Equipment Protection Levels based on Zones, from AS/NZS 60079.14:2022

Zone	State	Equipment Protection Level
0	Gas	Ga
1		Ga or Gb
2		Ga, Gb or Gc
20	Dust	Da
21		Da or Db
22		Da, Db or Dc

5.4 Equipment Type

AS/NZS 60079.14:2022 (Ref. [3]) details different types of protection that can be applied to meet the required EPL, and the applicable standard. **Table 5-7** shows the protection types that may be used in Ga zones while **Table 5-8** shows the protection types that may be used in Gb zones and **Table 5-9** shows the protection types that may be used in Gc zones. As the area is classified as Zone 2 NE, non-rated equipment can be used under normal conditions.

Table 5-7: Protection Codes for EPL Ga

EPL	Type of Protection	Code	Group	Reference	Comments
Ga	Intrinsically safe	ia	II	AS/NZS 60079.11	

EPL	Type of Protection	Code	Group	Reference	Comments
	Encapsulation	Ma	II	AS 2380.7	Where certified for use in Zone 0
				IEC 60079.11	
				AS/NZS 60079.18	
				IEC 60079.18	
	Two independent types of protection each meeting EPL Gb		II	AS/NZS 60079.26	
				IEC 60079.26	
	Protection of equipment and transmission systems using optical radiation		II	AS/NZS 60079.28	
				IEC 60079.28	
	Special protection	s	II	AS/NZS 1826	

Table 5-8: Protection Codes for EPL Gb

EPL	Type of Protection	Code	Group	Reference	Comments
Gb	Flameproof Enclosure	d	II	AS/NZS 60079.1	
				AS 2380.2	
				IEC 60079.1	
	Increased Safety	E	II	AS/NZS 60079.7	
				AS 2380.6	
				IEC 60079.7	
	Intrinsically safe	ia	II	AS/NZS 60079.11	
				AS 2380.7	
				IEC 60079.11	
	Encapsulation	Ma	II	AS/NZS 60079.18	
				IEC 60079.18	
	Oil immersion	O	II	AS/NZS 60079.6	
				IEC 60079.6	
	Pressurised Enclosure	P	II	AS/NZS 60079.2	
		Px		AS 2380.4	
		Py		IEC 60079.2	
	Powder filling	q	II	AS/NZS 60079.5	
				IEC 60079.5	
	Fieldbus intrinsically safe concept		II	AS/NZS 60079.27	AS/NZS 60079.27 Ed. 2.0:2008 only
				IEC 60079.27	
	Protection of equipment and transmission systems using optical radiation		II	AS/NZS 60079.28	Where certified for use in Zone 1
				IEC 60079.28	
	Special protection	s	II	AS/NZS 1826	

Table 5-9: Protection Codes for EPL Gc

EPL	Type of Protection	Code	Group	Reference	Comments
Gc	Intrinsically safe	ia	II	AS/NZS 60079.11	
				AS 2380.7	
				IEC 60079.11	
	Encapsulation	Ma	II	AS/NZS 60079.18	
				IEC 60079.18	
	Pressurised Enclosure	P	II	AS/NZS 60079.2	According to Zone 2 requirements
		Px		AS 2380.4	
		Py		IEC 60079.2	
	Protection of equipment and transmission systems using optical radiation		II	AS/NZS 60079.28	Where certified for use in Zone 2
				IEC 60079.28	
	Special protection	s	II	AS/NZS 1826	

5.5 Certification

Any equipment used must be certified under a recognised scheme. AUSEx, ANZEx and IECEx are the only Certification Schemes recognised for Hazardous Area use in Australia. All equipment used within the hazardous areas must carry at least one of these applicable certifications, imprinted on the equipment. It is noted that AUSEx and ANZEx are older schemes that are becoming less common. Hence, whilst not absolutely necessary, where possible, IECEx certified equipment should be considered above the other two schemes due to the availability of certification and the ongoing support provided by the IECEx organisation.

5.6 Hazardous Area Classification Table and Drawings

Based on the analysis conducted in **Section 4.0** a Hazardous Classification Table can be created. **Table 5-10** details all relevant information for the hazardous areas. However, no hazardous areas were identified in the assessment.

Table 5-10: Hazardous Area Classification Table

No	Source of Release	Flammable Material				Ventilation			Hazardous Area					
	Description	Grade of Release	Operating Temp, Pressure, State			Type	Dilution	Avail	Zone (0,1,2)	Zone Extent (m)		AS/NZS 60079.10.1 Ref.	Temp Class	Gas Group
			°C	kPa	L, G					Lateral	Vertical			
1	Aerosols	Secondary	20	Atmos	G	Mech	High	Fair	2	NE/NH	NE/NH	5.2 – Source of Release	T2	IIA

6.0 Conclusions and Recommendations

6.1 Conclusions

The Woolworths EPDC site at 29 Sarah Andrews Close, Erskine Park NSW was reviewed to determine the hazardous areas associated with storages and operations occurring at the site as part of ongoing risk assessment as required by the WHS Regulation. Based on the assessment, no hazardous zones were identified.

6.2 Recommendations

No recommendations have been made as part of this assessment.

7.0 References

- [1] SafeWork NSW, "Work Health and Safety Regulation," SafeWork NSW, Lisarow, 2017.
- [2] Standards Australia, "AS/NZS 3000:2018 - Wiring Rules," Standards Australia, Sydney, 2018.
- [3] Standards Australia, AS/NZS 60079.14:2022 - Explosive Atmospheres Part 14: Electrical Installations, Design, Selection and Erection, Sydney: Standards Australia, 2022.
- [4] Standards Australia, AS/NZS 60079.10.1:2022 - Explosive Atmospheres Part 10.1: Classification of Areas, Explosive Gas Atmospheres, Sydney: Standards Association of Australia, 2022.
- [5] Standards Australia, "AS/NZS 3833:2024 - Storage and Handling of Mixed Classes of Dangerous Goods, in Packages and Intermediate Bulk Containers," Standards Australia, Sydney, 2024.
- [6] F. P. Lees, Loss Prevention in the Process Industries, London: Butterworth-Heinemann, 2005.
- [7] J. Barry, "Estimating Rates of Spread and Evaporation of Volatile Liquids," *Chemical Engineering Progress (CEP) Magazine*, pp. 32-39, January 2005.

Appendix A

Gas Release

A1. Pool Size Model

The release rate of a gas (G_L) can be estimated using **Equation A-1**.

(Ref. [6]).

$$G_L = C_d A P_1 \left[\left(\frac{M\gamma}{RT} \right) \left(\frac{2\gamma}{\gamma + 1} \right)^{\left(\frac{\gamma+1}{\gamma-1} \right)} \right]^{0.5} \quad \text{Equation A-1}$$

Where

- G_L = gas release rate (kg/s)
- C_d = discharge co-efficient
- A = cross sectional area of the hole (m^2)
- M = molecular weight of the gas (g/mol)
- P_1 = Upstream pressure of the leak (MPa)
- γ = ratio of specific heats at constant pressure and constant volume (assumed to be 1.3)
- R = universal gas constant (8.314 J/mol.k)
- T = temperature (K)