Risk assessment of natural gas pipeline on proposed building at Kingswood Public School

For NSW Department of Education

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Summary

The NSW Department of Education (DoE) has proposed a new school building at Kingswood Public School at Kingswood, NSW. The existing school is located at 46-54, Second Avenue, Kingswood, NSW 2727. The school building will replace the existing demountable buildings at the school.

RP Infrastructure, on behalf of DoE, has engaged Arriscar Pty Limited (Arriscar) to undertake a Hazard Analysis to determine the risk impact on the proposed development from nearby Jemena gas distribution network primary gas main. Primary gas mains operate at lower pressures than transmission pipelines and do not require licensing.

A formal preliminary hazard analysis (PHA) in accordance with Hazardous Industry Planning Advisory paper (HIPAP) No.6 is not required by the NSW Planning circular PS 24-005 [1], as the Planning Circular applies only to licensed pipelines. However, a hazard analysis has been commissioned for the Primary Gas Main by DoE as part of its due diligence process.

The study assessed both the risk to occupants of the new school building and risk of thermal radiation and gas explosion impact on the building. The risk to occupants was evaluated against the risk criteria in HIPAP No.10 [2].

Conclusions

The hazard analysis made the following conclusions:

- The risk from the gas pipeline does not exceed any locational specific risk in relation to fatality, injury, or property damage at the school boundary, specified in HIPAP No.10 [2].
- Thermal radiation exceeding 4.7 kW/m^2 from a full bore rupture of the gas pipeline does not reach the proposed development.
- The maximum thermal radiation on the proposed building is 4 kW/m^2 at a frequency of 3.4×10^{-12} p.a. which is negligible.
- The maximum blast impact on the school building is 1.5 kPa at 8.3×10^{-11} p.a. The risk is negligible and at 1.5 kPa overpressure, there will be no adverse impact on the school building structure.
- A societal risk was not undertaken as there is no requirement for a PHA under the NSW Planning circular PS 24-005 [1] for the gas pipeline which is not a licensed pipeline.

Mitigation Measures

No mitigation measures are required for the proposed activity as there is no impact from a gas release on the proposed school structures.

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Notation

Abbreviation	Description
ALB	Automatic Line Break
Arriscar	Arriscar Pty Ltd
AS	Australian Standard
BoM	Bureau of Meteorology
BYDA	Before You Dig Australia
CH4	Methane
DAL	Design Accident Load
DCVG	Direct Current Voltage Gradient
DoE	NSW Department of Education
DPHI	Department of Planning, Housing and Infrastructure
EP&A	Environmental Planning & Assessment
FBR	Full Bore Rupture
HDD	Horizontal Directional Drilling
HDPE	High density Polyethylene
HIPAP	Hazardous Industry Planning Advisory Paper
IOGP	International Offshore Oil & Gas producers Association
kg/s	Kilograms/ second
km	kilometres
KP	Kilometre Point (pipeline distance measurement)
kPa	Kilo Pascals
kW/m^2	Kilo Watts per square metre
LFL	Lower Flammability Limit
LSIR	Location-Specific Individual Risk
m	metres
m/s	Metres per second
MAOP	Maximum Allowable Operating Pressure
mg/m^3	milligrams per cubic metres
mm	millimetres
MPag	Megapascals gauge
N/A	Not Applicable
ND	Nominal Diameter

Abbreviation	Description
NG	Natural Gas
NR	Not Reached
OBRA	Occupied Building Risk Assessment
OSHA	Occupational safety and Health Agency (USA)
p.a.	per annum
PHA	Preliminary Hazard Analysis
REF	Review of Environmental Factors
s	Seconds
SEPP	State Environmental Planning Policy
TPA	Third Party Activity
UK HSE	United Kingdom Health & Safety Executive
UKOPA	United Kingdom Onshore Pipeline Operators' Association
v/v	volume/volume
VCE	Vapour Cloud Explosion
vol. %	Percent by volume

1 INTRODUCTION

1.1 Background

The NSW Department of Education (DoE) is proposing to construct new teaching spaces in a single storey building at the Kingswood Public School, located at 46-54, Second Avenue, Kingswood, NSW 2747. The development involves removal the existing demountable classrooms and replace with a new building.

Arriscar Pty Ltd (Arriscar) was engaged by RP Infrastructure on behalf of the NSW Department of Education to undertake an assessment of risks from a natural gas pipeline in the vicinity of Kingswood Public School, and impact on proposed new building. No increase in school population is planned.

This risk assessment report has been prepared to accompany a Review of Environmental Factors (REF) for the Department of Education (DoE) for upgrades to Kingswood Public School (the activity) under Part 5 of the Environmental Planning and Assessment Act 1979 (EP&A Act) and State Environmental Planning Policy (Transport and Infrastructure) 2021 (SEPP TI).

This document has been prepared in accordance with the Guidelines for Division 5.1 assessments (the Guidelines) by the Department of Planning, Housing and Infrastructure.

This report examines and takes into account the relevant environmental factors in the Guidelines and *Environmental Planning and Assessment Regulations 2021* under Section 170, Section 171 and Section 171A of the EP&A Regulation.

1.2 Scope

The scope of the study included undertaking a risk assessment on the new building at Kingswood Public School from the Jemena Primary Natural Gas main, in accordance with HIPAP No.6 [3]:

The scope also included an assessment of the risks to the proposed school hall from the pipeline in accordance with HIPAP No. 10 [2].

This study mainly focuses on the consequence impact of gas releases from the pipeline on the proposed new buildings, and estimation of Design Accidental Load (DAL) on the building.

- Identification of gas release hazards from the Jemena primary gas main in the vicinity of the development;
- Development of appropriate and relevant representative gas release scenarios that may impact on the school site;
- Quantification of the consequences of harmful effects for each representative scenario (fires, explosions, exposure to unignited gas), including the potential for impact on the proposed development;
- Quantification of the likelihood of occurrence of each representative scenario;
- Generation of Location-Specific Individual Risk (LSIR) contours for comparison with the DPE's risk criteria for land use safety planning , viz. as per HIPAP No.4 [4] and HIPAP No.10 [2]; and
- Estimation of DAL from fires and explosions on the new school building.

2 PROPOSED DEVELOPMENT AND SURROUNDING LAND USES

2.1 Site Location

Kingswood Public School is an existing educational facility and is located on 46-54, Second Avenue Kingswood, NSW 2747, in the local government area of Penrith. The site is legally described as Lot 172 in Deposited Plan (DP) 839785. Kingswood Public School is located on the southern side of Second Avenue.

The school location map is shown in Figure 1.

Figure 1: Kingswood Public School Location Map

2.2 Surrounding Land Uses

The Kingswood Public School is located on the south side of Second Avenue. The surrounding land uses are:

West: Low density residential developments between the school site and Manning Street.

North: Open space – Chapman Gardens Oval

East: University of Western Sydney – Penrith campus

South: Residential aged care home.

There is a natural gas (NG) distribution pipeline operated by Jemena to the north of the school site, along Second Avenue.

The Jemena pipeline is classified as a primary gas main in the Jemena Gas Network (JGN) and supplies gas to customers in the area.

The pipeline is shown in Figure 2.

Figure 2: Jemena Gas Pipeline Location

The blue line in the above figure indicates the buffer distance from the pipeline, based on AS 2885.6-2018 [5]. Developments within the buffer zone would need closer scrutiny for potential interaction with the pipeline. The northern part of the school site falls within the buffer zone, but the proposed activity will be in the southern part of the site, outside the buffer zone.

2.3 Meteorology

Meteorology used for the analysis is based on Penrith weather station (ID: 066137), and is presented in Table 1.

Table 1: Average Temperature, Relative Humidity and Solar Radiation (Day)

Weather Category	Stability Class	Wind Speed (m/s)	Average Temp (°C)	Average Solar Radiation (kW/m^2)	Average Relative Humidity
1.8B	B	1.8	21.4	0.60	57
7.5D	D	7.5	22.8	0.46	42
3.9D	D	3.9	21.1	0.34	58
1.7D	D	1.7	18.4	0.28	73

Table 2: Average Temperature, Relative Humidity and Solar Radiation (Night)

Weather Category	Stability Class	Wind Speed (m/s)	Average Temp (°C)	Average Solar Radiation (kW/m^2)	Average Relative Humidity
7.3D	D	7.3	16.1	0	62
4.0D	D	3.6	16.3	0	78

Weather Category	Stability Class	Wind Speed (m/s)	Average Temp (°C)	Average Solar Radiation (kW/m²)	Average Relative Humidity
0.8D	D	1.1	13.7	0	90
2.6E	E	2.9	15.9	0	77
0.7F	F	1.0	13.3	0	90

The distribution of the weather categories in relation to wind direction is shown in Table 3.

Table 3: Directional Distribution of Weather Categories (Day)

Stab. Class	Wind Speed (m/s)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NWW	Total
B	**1.8**	0.0567	0.0386	0.0247	0.0171	0.0187	0.0149	0.0185	0.0197	0.0271	0.0161	0.0143	0.0090	0.0103	0.0084	0.0163	0.0219	0.3321
D	**7.5**	0.0073	0.0032	0.0018	0.0030	0.0041	0.0088	0.0106	0.0073	0.0114	0.0103	0.0076	0.0077	0.0232	0.0145	0.0077	0.0036	0.1321
D	**3.9**	0.0213	0.0103	0.0066	0.0051	0.0065	0.0054	0.0058	0.0084	0.0188	0.0134	0.0096	0.0043	0.0048	0.0031	0.0074	0.0091	0.1399
D	**1.7**	0.0391	0.0278	0.0220	0.0193	0.0275	0.0256	0.0237	0.0240	0.0567	0.0519	0.0231	0.0112	0.0173	0.0096	0.0078	0.0094	0.3960
Total		0.1243	0.0798	0.0551	0.0445	0.0567	0.0547	0.0586	0.0594	0.1139	0.0918	0.0545	0.0323	0.0557	0.0355	0.0392	0.0440	1.0000

Table 4: Directional Distribution of Weather Categories (Night)

Stab. Class	Wind Speed (m/s)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NWW	Total
D	**7.3**	0.0014	0.0004	0.0001	0.0000	0.0000	0.0001	0.0004	0.0011	0.0032	0.0049	0.0041	0.0017	0.0043	0.0022	0.0010	0.0007	0.0256
D	**3.6**	0.0339	0.0179	0.0144	0.0142	0.0135	0.0086	0.0125	0.0205	0.0719	0.0586	0.0375	0.0254	0.0344	0.0191	0.0151	0.0143	0.4118
D	**1.1**	0.0225	0.0080	0.0069	0.0080	0.0065	0.0055	0.0084	0.0153	0.0520	0.0824	0.0341	0.0113	0.0180	0.0135	0.0089	0.0096	0.3108
E	**2.9**	0.0042	0.0019	0.0017	0.0023	0.0023	0.0016	0.0014	0.0019	0.0077	0.0106	0.0046	0.0019	0.0028	0.0021	0.0015	0.0016	0.0500
F	**1.0**	0.0176	0.0095	0.0078	0.0073	0.0081	0.0050	0.0058	0.0100	0.0323	0.0280	0.0182	0.0107	0.0159	0.0105	0.0078	0.0075	0.2019
Total		0.0797	0.0376	0.0308	0.0318	0.0305	0.0208	0.0284	0.0488	0.1671	0.1844	0.0985	0.0510	0.0754	0.0475	0.0342	0.0337	1.0000

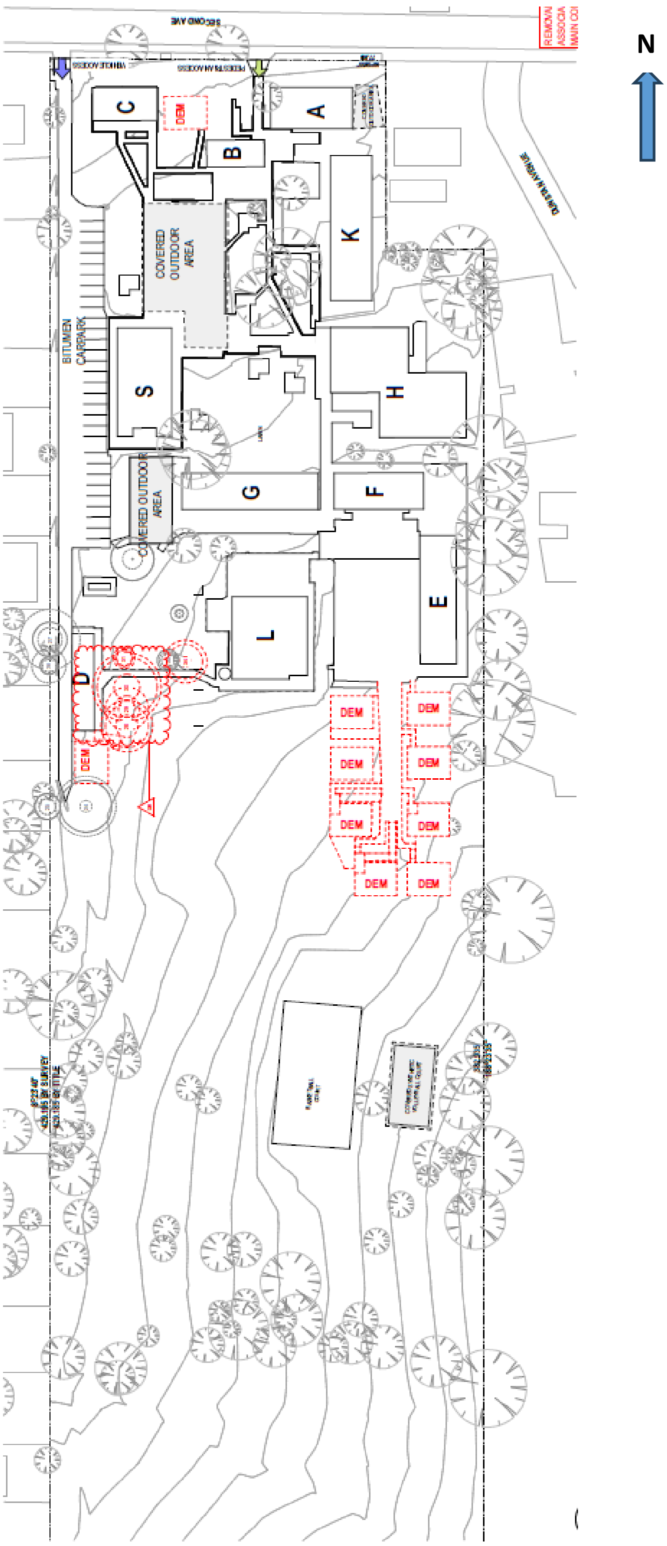
No single weather direction dominates the wind pattern. Moderately unstable (Stability D) and Neutral (Stability D) stability at low wind speeds dominates most of the time during the day. Stable weather conditions prevail (F stability) only for 20% of the time at night.

3 Outline of Proposed Development

3.1 Buildings

The existing school has a number of demountable buildings containing ten (10) class rooms on the south. A layout of the existing school, showing the demolition plan, is shown in Figure 3.

Figure 3: Existing Kingswood Public School Layout

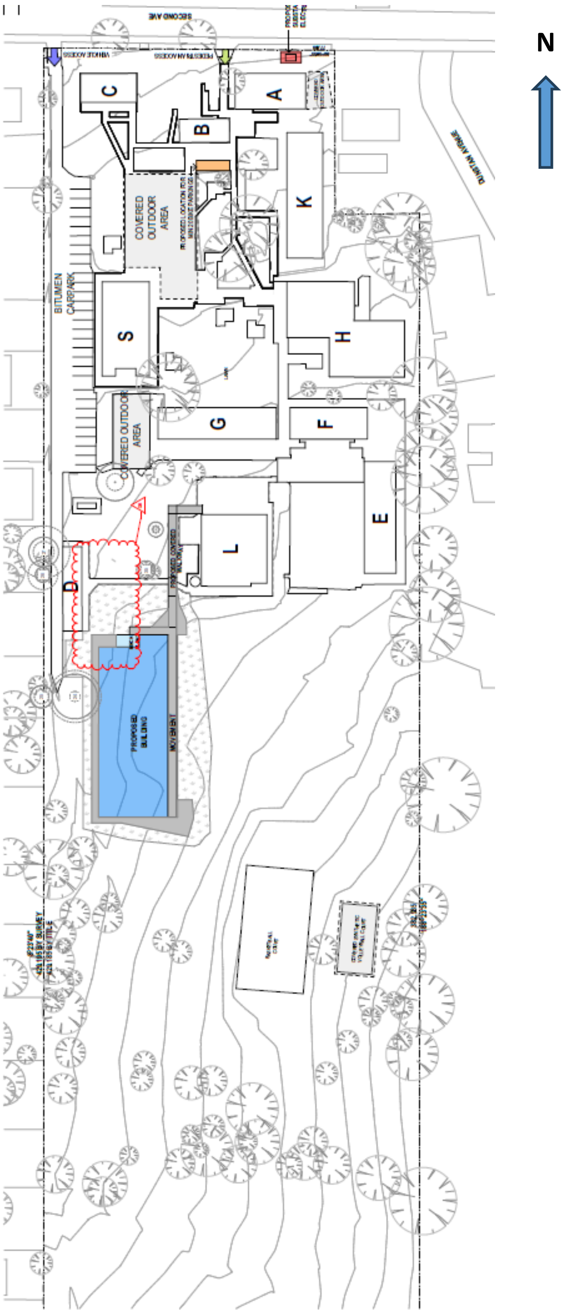


The proposed development consists of the following activities:

- One (1) new single storey classroom building comprising eight (8) general learning spaces (GLS), two (2) learning commons areas, two (2) multi-purpose spaces and a veranda along the eastern side of the building;
- The construction of a covered walkway that will provide a connection between the proposed classroom building and an existing covered outdoor learning area (COLA) to the north east of the proposed building; and
- Removal of existing portable classroom buildings containing ten (10) classrooms.

The proposed layout is shown in Figure 4.

Figure 4: Proposed Building Layout in Kingswood Public School



The distance between the pipeline on Second Avenue and the northern wall of the proposed building is approximately 375m.

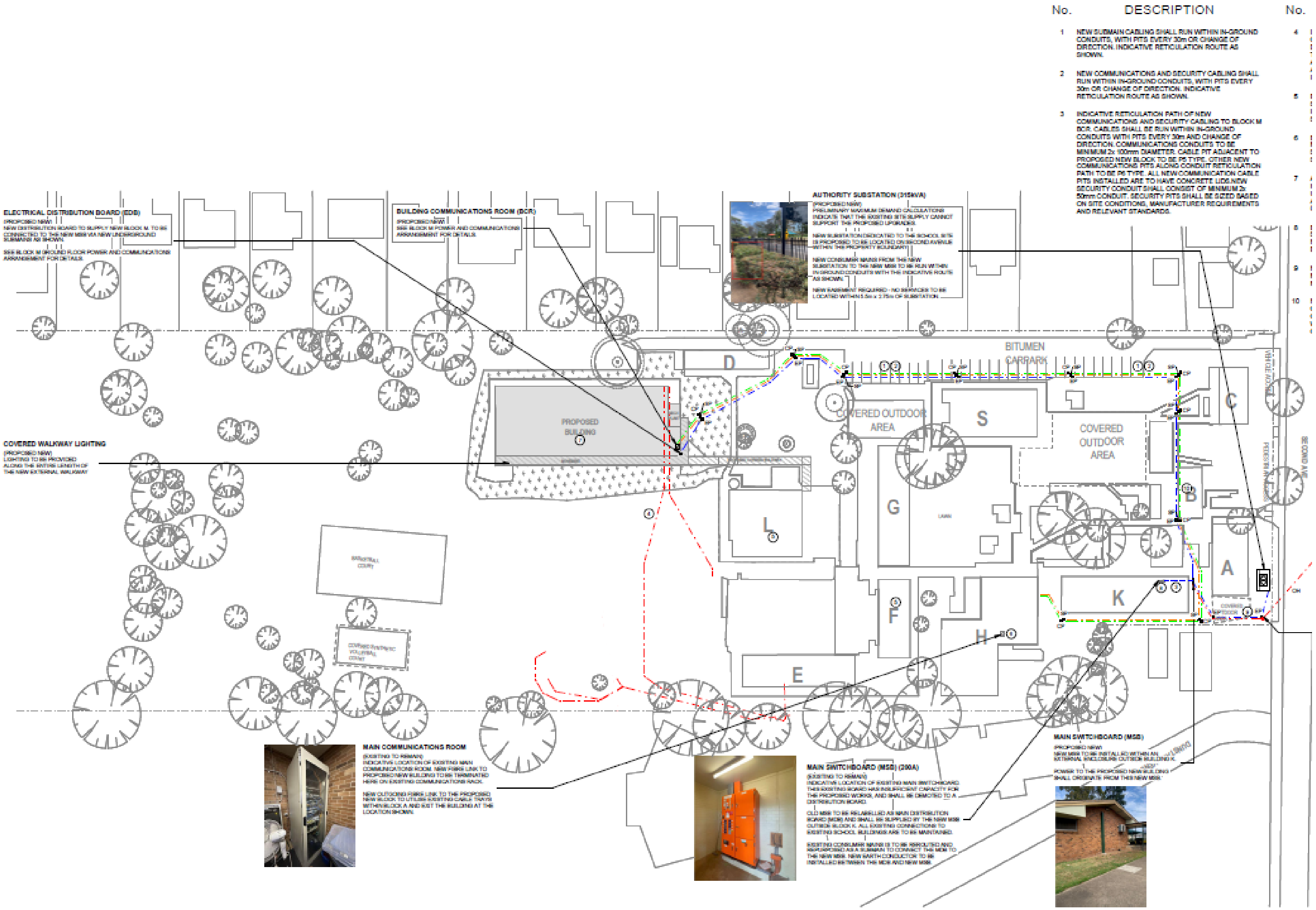
3.2 Electrical Upgrades

- Associated with the activity are upgrades to the electrical system. These include:
- A new 500 kVA substation dedicated to the school site to be located on Second Avenue within the property boundary
- New consumer mains from new substation to a new Main Supply Board within in-ground conduits in a new easement
- New electrical distribution board to new Block M, connected to the Main Supply Board
- New 35 kW solar array on new Block M
- Building Communications Room in new Block M
- Existing pole-mounted substation currently supplying power to the school to be disconnected
- Existing consumer mains to be disconnected

The pipeline runs along Second Avenue and is within the buffer distance from the pipeline. The distance from the pipeline and the proposed new substation is approximately 20 m.

A layout of electrical for the site is shown in Figure 5.

Figure 5: Electrical Systems Layout Diagram



4 Overview of Gas Pipeline

Information for the Primary gas main natural gas pipelines is listed in Table 5 [6]. The pipeline is much smaller than other primary gas mains, with a diameter of 200mm.

Table 5: Natural Gas Pipeline

Jemena Gas Network Primary Main	
Pipeline Owner	Jemena Ltd
Pipeline Name	Primary Gas Main
Material/Product Transferred	Natural Gas
Licence No.	Licence not required
MAOP	3.5 MPa
Normal Operating Pressure	Primary mains typically operate at > 1.75 MPag to 3.5 MPag [7]
Operating Temperature	15°C
Flowrate	12.1 kg/s (average based on GWh supplied to industries in 2022, Ref. [8]. Peak value of 100 kg/s was assumed.
Pipeline Material	N/A
Pipeline Diameter	DN200
Wall Thickness	Assumed 8.1mm
Depth of Cover	*Information not provided* (Note: Surveyed pipeline depths have observed to be marked on the roadways in various locations and found to be within 500mm to 1000mm in depth
Cathodic Protection	Primary and Secondary mains are typically provided with CP, which is periodically monitored [7]
External Coating	*Information not provided* Typically coated with High-Density Polyethylene (HDPE) or Tri-laminate product and internally lined to reduce frictional loses and provide some internal corrosion protection [7]
Leak Detection	*Information not provided*
Locations of Nearest Isolation Valves	*Information not provided*
Leak Detection Time	NA
Leak Isolation Time	NA
Inspections and Maintenance	*Information not provided* Integrity is assessed through integrity and performance assessments, such as Direct Current Voltage Gradient (DCVG) measurement [7]
Control Measures for 3rd Party Interference	Warning Signage, DBYD, patrols

5 HAZARD IDENTIFICATION

5.1 Introduction

The hazard identification was based on a review of the information on the NG pipeline (Refer to Section 3); properties of NG; and potential failure modes and consequences if a leak were to occur from a pipeline.

The representative release scenarios carried forward to the consequence analysis are listed in Section 6.1.1.

5.2 Properties of Natural Gas

Natural Gas is principally used as a fuel. It typically contains 95 to 97% methane (CH_4) and is modelled as methane in the risk analysis.

Physical properties are listed in Table 6.

Table 6: Physical Properties of Methane

Boiling Point °C	-162
Flash Point °C	-218
Autoignition Temperature °C	540
Relative Density (Air =1)	0.55
Lower Flammability Limit in air (vol. %)	4.4
Upper Flammability Limit in air (vol. %)	16.5

Methane is:

- A gas at ambient conditions;
- A gas at typical operating conditions for Natural Gas pipelines;
- Flammable;
- Lighter than air at ambient temperatures; and
- Colourless, odourless and non-toxic (Note: Natural Gas is not odourless).

5.3 Pipeline Failure Modes

Pipelines may leak due to various causes. The four principal failure modes that may result in a leak from an underground pipeline include [9]:

- **Mechanical failures**, including material defects or design and construction faults;
- **Corrosion**, including both internal and external corrosion;
- **Ground movement and other failure modes**, including ground movement due to earthquakes, heavy rains/floods or operator error, and other natural hazards such as lightning, etc.; and
- **Third Party Activity (TPA)**, including damage from heavy plant and machinery, damage from drills/boring machines and hot tapping, etc.

5.3.1 Mechanical Failure

Leaks due to mechanical failures are usually caused by a construction fault, a material fault / defect or design of the pipeline.

This failure mode is credible for both pipelines; however, historical incident data for other pipelines indicates this is generally a low likelihood failure mode, particularly for more recently manufactured pipelines (i.e., post 1980).

5.3.2 Corrosion

Leaks due to internal corrosion are generally a function of the material being transported, the wall thickness of the pipeline and the materials of construction.

Leaks due to external corrosion do not depend on the material being transported and are generally dependent on the soil type / conditions, pipeline coating and materials of construction, and the age of the pipeline.

This failure mode is credible for both pipelines; however, historical incident data for other pipelines indicates this is a low likelihood failure mode, particularly for pipelines with a higher wall thickness (i.e., > 10 mm) and more recently manufactured pipelines (i.e. post 1980).

5.3.3 Ground Movement and Other Failure Modes

Pipeline leaks may occur due to ground movement (e.g. following a landslide or earthquake). The potential also exists for ground movement in the vicinity of water crossings (water erosion) or as a result of construction activities (new road infrastructure and buildings).

Other external events, such as lightning strikes, operational errors and erosion may also lead to a leak.

This failure mode is credible for both pipelines; however, the local topography is such that this is expected to be lower likelihood than would apply for areas with more potential for ground movement.

5.3.4 Third Party Activity

Most leaks due to Third Party Activity (TPA) are caused by construction vehicles and equipment (drills, etc.) or by farm machinery in rural areas. The leak typically occurs immediately upon contact; however, it may be delayed (i.e., if the TPA only weakens the pipeline such that it fails at a later time).

Leaks due to TPA include those caused by horizontal directional drilling (HDD), which is commonly used to install utilities and services (communication cables, etc.).

Leaks due to TPA are particularly relevant when considering development in the vicinity of existing pipelines due to the potential for significant construction activities (e.g. new road infrastructure and buildings).

This failure mode is credible for both pipelines.

5.4 Consequences of Gas Release

5.4.1 Asphyxiation

Although non-toxic, Ethane and Methane have the potential to cause asphyxiation at higher concentrations due to oxygen depletion, particularly if exposure occurs in a confined space.

Methane and Ethane are simple asphyxiants with low toxicity to humans. If a release does not ignite, then the potential exists for the gas concentration to be high enough to present an asphyxiation hazard to individuals nearby.

An atmosphere with marginally less than 21% oxygen can be breathed without noticeable effects. However, at 19.5% (which is OSHA's lower limit for confined space entry in 29 CFR 1915.12 [10]) there is a rapid onset of impairment of mental activity.

An oxygen concentration of about 15% will result in impaired coordination, perception and judgment. This may prevent a person from performing self-rescue from a confined space.

The potential for unconsciousness and fatality is only significant at less than 10% oxygen. However, to reduce the oxygen concentration to 10% requires a relatively high concentration (viz. approximately 52% v/v, which equates to 342,000 mg/m^3 for Methane).

Oxygen deficiency from exposure to methane should not be a major issue because the fire hazards are usually the dominant effects in most locations (the LFL for methane is approximately one-tenth of the fatal asphyxiant concentration). Therefore, the potential for fatality from asphyxiation was not carried forward to the consequence, likelihood and risk estimation steps.

5.4.2 Jet Fire

Release of methane released from high pressure through a hole in a pipeline may create a jet plume. The gas plume extends several metres in the direction of discharge due to its momentum jet effect, entraining air. Ignition would result in a jet fire.

The potential for fatality due to exposure to heat radiation from a jet fire (including direct exposure to the jet) was included in the risk assessment.

5.4.3 Flash Fire

Ignition of an unconfined gas or vapour cloud will usually progress at low flame front velocities and will not generate a significant explosion overpressure. Unobstructed combustion of the gas cloud is referred to as a flash fire, which has the potential to cause injuries or fatalities for individuals within the ignited cloud.

5.4.4 Vapour Cloud Explosion

A high degree of confinement and congestion is required to produce high flame speeds (i.e. > 100 m/s) in a flammable gas or vapour cloud, due to promotion of turbulence and accelerated combustion. This may occur inside buildings and around obstacles (e.g., buildings, vehicles, trees etc.).

5.4.5 Gas Ingress into Buildings

The gas jet would disperse downwind once the momentum effect is lost. If the wind direction were oriented towards the school buildings, there is potential for flammable gas to be drawn into the buildings through ventilation air intake, and through open windows. If the gas reaches lower flammability limit, an ignition within the building would result in a confined explosion with serious harm to occupants and structural damage.

6 CONSEQUENCE ANALYSIS

6.1 Gas Releases

6.1.1 Representative Hole Diameter

Representative hole diameters were selected for the consequence modelling. These were selected to align with the leak frequency data (Refer to [9]), which includes four hole size categories:

- Pinhole (≤ 25 mm);
- Small Hole (> 25 mm to ≤ 75 mm);
- Large Hole (> 75 mm to ≤ 110 mm); and,
- Rupture (> 110 mm).

The representative hole diameter/s in each hole size category were selected based on the UK HSE database for pipelines [9].

6.1.2 Rate of Release

Release events were modelled using the 'Long Pipeline' model in the SAFETI software package (Version 9.0). The estimated release rates are tabulated below for each representative hole size.

For each representative hole diameter, the release rate for each section of the long pipeline was calculated as the average release over a 30 second period.

6.1.3 Height and Orientation of Release

The SAFETI software does not permit entry of a release height below 0 m; therefore, all releases from the underground pipeline were modelled at a release height of 0 m (i.e. ground level). This is not a significant factor for the typical burial depth.

Full bore rupture releases were modelled as vertical releases. For smaller hole sizes, two release directions are possible. Releases from top of the pipeline were modelled as vertical releases and releases from middle of the pipeline were modelled as horizontal releases.

6.1.4 Duration of Release

Methane is flammable and any adverse impact will occur quickly (fire or explosion); therefore, the duration of exposure is not as critical as it would be if there were a toxic material in the pipelines (i.e. where the adverse impact can significantly increase for longer exposure durations).

The isolation time and duration of release is not specified in the risk assessment as these will be significantly longer than the period of exposure required for an adverse effect to people and the time required for each representative release case to reach steady state.

Duration of release becomes significant only from a fire escalation point and not required for risk assessment based on short duration exposure to fire.

6.2 Fire Modelling

SAFETI 9.0 was used to model all the representative fire events included in the risk analysis.

6.2.1 Jet Fire

Example distances to heat radiation levels of 4.7, 12.5, 23 and 35 kW/m^2 are tabulated in Appendix A.1.1 for representative jet fire events included in the risk analysis.

For a full-bore rupture (FBR) of the Jemena NG pipeline, distance to 4.7 kW/m^2 was 72m because of lower pressure (3.5 MPag MAOP).

A thermal radiation of 4.7 kW/m^2 does not reach the new school building.

6.2.2 Flash Fire

Example distances to the lower flammability limit (LFL) concentration are tabulated in Appendix A.1.2 for representative flash fire events included in the risk analysis.

Maximum distance to LFL was calculated as 60m for a 100mm horizontal release and would not reach the new school building.

6.3 Vapour Cloud Explosion

When a flammable vapour cloud ignites, the flame front advances as the cloud burns. If there are obstacles in the path of the flame front, the level of turbulence increases causing accelerated burning and thus the flame front accelerates, reaching speeds of 100-200 m/s. The whole combustion process occurs over a period of less than a second, but this short burst of high speed flame front results in a blast wave, resulting in a pressure above the atmospheric pressure on the target surface (referred to as blast overpressure).

The blast wave can cause damage to the structure and injury/ fatality to exposed individuals and is commonly called vapor cloud explosion (VCE).

Results are provided in Appendix A.1.3.

.The following findings were made:

- None of the releases generated overpressures above 7 kPa;
- Only horizontal releases from the pipeline generated an explosion overpressure of 7 kPa. The distances were 41m for a 110mm hole and 29m for a 75mm hole.
- Gas releases do not cause an overpressure of 7 kPa at the new school building.

6.4 Impact on New Sub-Station

The distance from the pipeline to the new substation is approximately 20m. The distance to a thermal radiation of 23 kW/m^2 for a full-bore rupture is calculated as 17m (see Appendix A). The thermal radiation on the substation would be between 12.5 kW/m^2 and 23 kW/m^2. Some damage to the substation may result, but shutdown of the gas main and rapid depressuring would reduce the duration of exposure.

This is an existing risk even for the current pole-mounted substation.

7 FREQUENCY AND LIKELIHOOD ANALYSIS

7.1 Likelihood of Gas Release

The likelihood of a gas release (i.e. leak) from each of the HP pipelines is tabulated in Table 7 and was estimated based on UK Health and Safety Executive (HSE), Research Report (RR) 1035 [9].

Table 7: Leak Frequencies

MAE	Leak Frequency (per km per yr)				
	Pinhole (≤ 25 mm)	Small Hole (> 25 mm to ≤ 75 mm)	Large Hole (> 75 mm to ≤ 110 mm)	Rupture (> 110 mm)	Total Leak Frequency
Release of Natural Gas (Methane) from Jemena Primary Main	7.57E-05	4.92E-06	2.67E-07	2.62E-06	8.35E-05

7.2 Probability of Ignition

The ignition probabilities adopted in the risk analysis are based on the built-in default values in SAFETI, using the data of IOGP [11].

8 Risk Analysis

8.1 Individual Risk of Fatality

The risk contours for individual risk of fatality at 0.5 x 10^{-6} per annum (p.a.) and higher for the pipeline were not generated.

The risk criterion HIPAP No.10 [2] for sensitive land uses (i.e., the School), is therefore satisfied.

8.2 Risk of Injury (Exceeding 7 kPa)

The cumulative risk of injury (Overpressure exceeding 7 kPa) does not reach 50 x 10^{-6} per annum; therefore the proposed school development complies with the relevant DPHI risk criterion.

8.3 Risk of Injury (Exceeding 4.7 kW/m^2)

The cumulative risk of injury (Heat radiation exceeding 4.7 kW/m^2) does not reach 50 x 10^{-6} per annum. Therefore the proposed school development complies with the relevant DPHI risk criterion.

9 RISK-BASED DESIGN LOADS FOR FIRES AND EXPLOSIONS

9.1 Exceedance Curves Methodology

There are two methods available for determining the design accidental load (DAL) for fires and explosions [12]:

(a) Consequence-Based

This approach only takes account of the impact of the maximum credible event for each building, irrespective of its frequency. A thermal load in kW/m^2 and a blast side-on overpressure in kPa are selected for the building design. The worst credible event (Consequence-Based) approach can lead to blast loads that are far too large to be accommodated by the structures to be protected.

(b) Risk-Based

This approach considers both the consequences and the frequencies of *all* the potential fire and explosion scenarios that impact on a specific building. It enables design of the structures to resist reasonable thermal radiation values and lower overpressure values, accepting explicitly a certain residual risk of exceeding the thermal radiation or explosion overpressure design value.

The most common Risk-Based method includes the development of Exceedance Curves.

Heat flux or overpressure exceedance curves represent the cumulative frequency of exceeding any heat flux or overpressure value for a given location. The use of exceedance curves requires a target value for the frequency that a building is subject to an accident load higher than the design load.

The exceedance curve approach was developed by the UK Chemical Industry Association [13] and is widely used for determining the thermal radiation load and blast overpressure load for Occupied Buildings Risk Assessment (OBRA). One of the strengths of the exceedance curve approach is that it displays the range of potential scenarios, rather than a single event. This method has been endorsed by the HSE in the UK [14].

The cumulative frequency is used because the risk-based approach requires identification of a hazard level which will not be exceeded at a given frequency. This is different from identifying a discrete hazard level which occurs at a particular frequency.

The exceedance curve is generated as follows:

- Select a target building/location.
- Construct a table of the frequency - heat flux pairs for all fire scenarios from both the SNP and potential future Jet Fuel pipelines.
- Sort the table in descending order of heat flux and calculate the cumulative frequency with which the given heat flux would be exceeded.
- Read off from the exceedance curve the heat flux corresponding to the target frequency. This becomes the risk-based design accidental load for the structure for fires.
- Construct similar curves for all buildings and select the largest heat flux among them as the design accidental load.

A similar procedure is applied for the overpressure exceedance curve.

9.2 Setting Target Frequency for Exceedance Analysis

The UK Chemical Industries Association Guidance [13] requires buildings to be designed to resist overpressure scenarios characterized by a frequency of 10^{-4} occurrences/y and suggests that less frequent events need not to be considered. UKOOA & UK HSE [14] state that a frequency between 10^{-4} and 10^{-5} exceedances per year can be considered a reasonable target frequency.

It is clear that 10^{-5} p.a. is the lowest frequency suggested for buildings in an industrial site. Benucci et al. [15] have suggested blast load exceedance frequencies are 10^{-5} per annum for Unmanned Buildings and 10^{-6} p.a. for Manned Buildings.

For the present study, the following cumulative frequencies have been adopted:

Occupied building: 1×10^{-6} p.a.

Unoccupied building: 1×10^{-5} p.a.

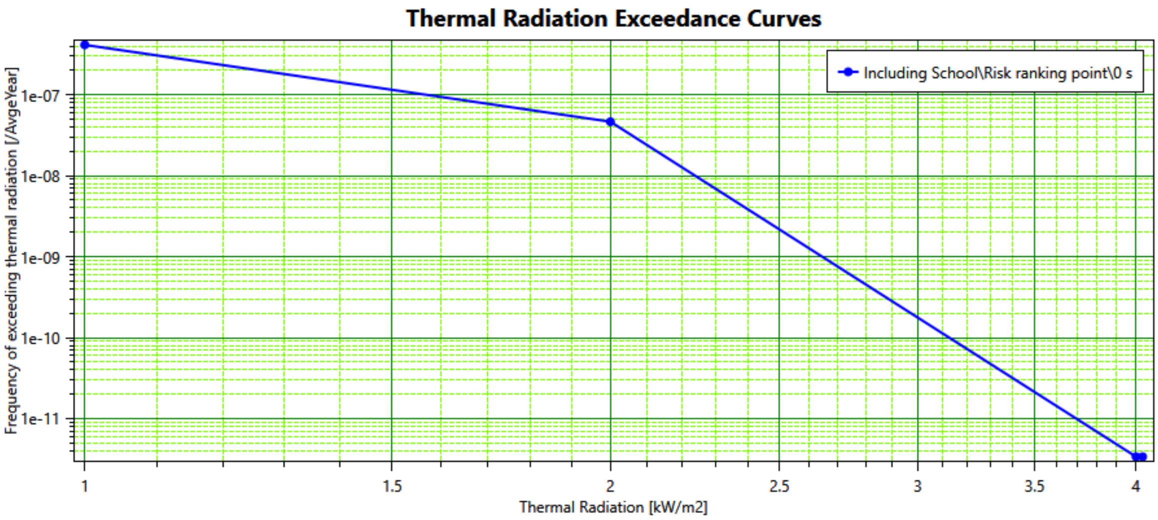
The same target frequency is used for both fire load and blast load.

9.3 Exceedance Analysis for Fire Load on the School Building

The methodology for the determination of target design blast load for the buildings is similar to that for the fire load.

The exceedance curve for fire load generated in SAFETI 9.0 is shown in Figure 5.

Figure 6: Exceedance Curve for Fire Radiation at the proposed School Building



The exceedance curve is shown for school the building location (north wall, which is closest to the pipeline). The following observations can be made:

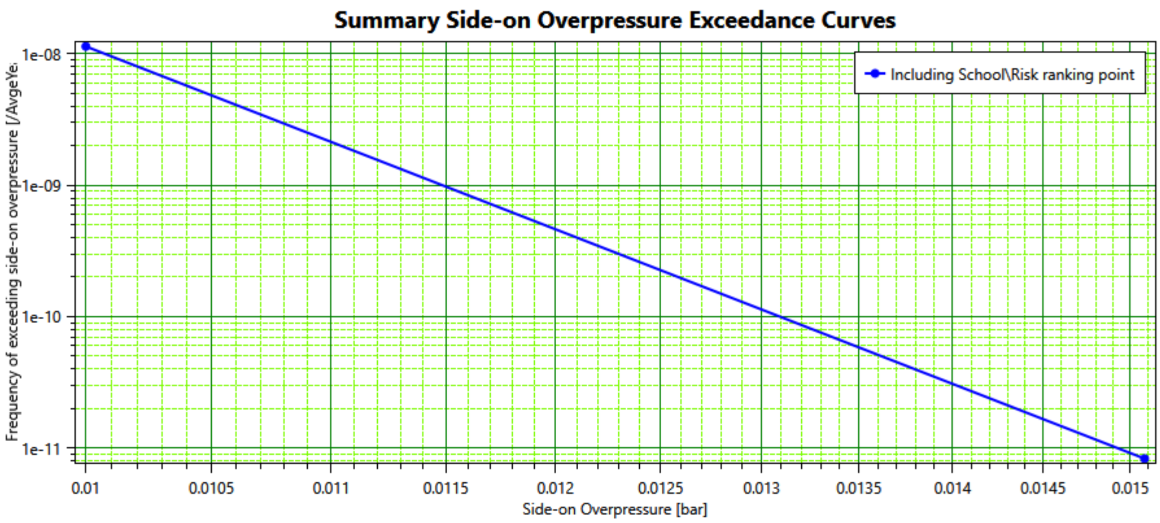
- A cumulative frequency of 1×10^{-6} p.a. does not result.
- A thermal radiation of 4.7 kW/m2 on the building wall is not reached.
- The maximum thermal radiation on the building is 4 kW/m^2 at a cumulative frequency of 3.4×10^{-11} p.a. This risk is negligible.

9.4 Exceedance Analysis for Blast Load on the School Building

The methodology for the determination of target design blast load for the buildings is similar to that for the fire load.

Exceedance curves for the blast overpressure on the two location options for the school hall were generated in SAFETI 9.0. These curves are provided in Figure 6.

Figure 7: Exceedance Curve for Blast Overpressure at the proposed School Building



The following observations can be made:

- There are no events producing an overpressure on the school building at a cumulative frequency higher than of $1x10^{-8}$ p.a.
- The maximum side-on overpressure on the school building is 1.5 kPa at a frequency of 8.3E-11 p.a. The frequency is negligible. An overpressure of 1.5 kPa would have no adverse impact on the structural integrity of the building.

A societal risk curve was not calculated as the pipeline is not licensed and there is no requirements for a PHA according to the Planning Circular 24-005 [1].

9.5 Risk of Fire Damage to New Substation

The frequency of a pipeline fire with thermal radiation between 12.5 kW/m^2 and 23 kW/m^2 at the substation is less than $1x10^{-6}$ p.a. While there is no established risk criteria for asset protection, a value less than 1.0E-05 p.a. is generally accepted as 'tolerable risk' in industry practice as the area is normally unoccupied [15].

Risk mitigation measures for substation protection, other than fire protection specified by the codes are not considered necessary.

10 CONCLUSIONS AND MITIGATION STRATEGIES

10.1 Conclusions

The following conclusions were arrived at in the study:

1. The risk from the gas pipeline on the proposed activity satisfies the risk criteria specified in HIPAP No.10 [2].
2. On a consequence basis alone, thermal radiation from a potential pipeline rupture gas fire does not affect the proposed activity.
3. On a consequence basis alone, a gas explosion from a potential pipeline rupture does not affect the structures in the proposed activity.
4. The risk of fire and asset damage for the new substation is low and is l

10.2 Mitigation Strategies

There are no mitigation strategies arising out of the study.

11 REFERENCES

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Appendix A Consequence Analysis – Example Data and Results

Hazard ranges for the modelled release cases are tabulated in this Appendix. Only daytime results are included as these are most applicable for operation of the proposed school building.

A.1.1 Example Jet Fire Consequence Analysis Results

Jet fire consequences are summarised in Table 8.

Table 8: Jet Fire Consequence Analysis Results for Natural Gas Pipeline (D7.5)

Release Scenario	Flame Length (m)	Downwind Distance to selected thermal radiation level (m)			
		4.7 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²
25 mm (MID)	11	17	9	2	N.R.
75 mm (MID)	30	49	27	10	N.R.
110 mm (MID)	37	63	34	13	N.R.
FBR*	43	72	40	17	N.R.

* At average release rate from 'Long Pipeline' model for t = 30 seconds after release

A.1.2 Example Flash Fire Consequence Analysis Results

Flash fire consequences are summarised in Table 9.

Table 9: Maximum Distances to LFL (D7.5)

Release Scenario	Distance to LFL (m)
25 mm (MID)	10
75 mm (MID)	42
110 mm (MID)	60

Note 1: Consequences calculated at 1m above ground level.

Note 2: Distances to LFL at 1m from ground were very short, < 1m for vertical releases

A.1.3 Example Explosion Results

Table 10: Distances to Explosion Overpressures

Release Scenario	Distance to 7 kPa (m)
25 mm (MID)	8
75 mm (MID)	29
110 mm (MID)	41

Note 1: Explosion overpressures above 7 kPa were not reached.