PRELIMINARY HAZARD ANALYSIS

TECHNICAL PAPER 6

PROPOSED GAS PIPELINE AND GAS TURBINES FOR THE MUNMORAH POWER STATION

Preliminary Hazard Analysis

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Revision History

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CONTENTS

ABBREVIATIONS

API	American Petroleum Institute
ANSI	American National Standards Institute
AS	Australian Standard
CONCAWE	Conservation of Clean Air and Water in Europe
DIPNR	Department of Infrastructure, Planning and Natural Resources
DN	Diameter Nominal
EA	Environmental Assessment
EGPIDG	European Gas Pipeline Incident Data Group
ESD	Emergency Shutdown
HIPAP	Hazardous Industry Planning Advisory Paper
KBR	Kellogg, Brown and Root Pty Ltd.
kV	kilo Volt
LEL	Lower Explosive Limit
LFL	Lower Flammability Limit
m	metre
MJ/Sm^3	Mega Joules/Standard cubic metre
mm	millimetre
MPa	Mega Pascal
OCGT	Open Cycle Gas Turbine
OD	Outer Diameter
P&ID	Piping & Instrumentation Diagram
p.a.	per annum
PHA	Preliminary Hazard Analysis
PLC	Programmable Logic Controller
QRA	Quantitative Risk Assessment
RTA	Roads and Traffic Authority, NSW
SCADA	Supervisory Control and Data Acquisition
Scm/h	Standard cubic metres per hour
SIL	Safety Integrity Level
SMYS	Specified Minimum Yield Strength
TÜV	Technischer Überwachungs-Verein (Technical Supervision Society)

UFL	Upper Flammability Limit
UV / IR	Ultra Violet / Infra Red
VCE	Vapour Cloud Explosion

1 Introduction

1.1 BACKGROUND

Delta Electricity is proposing to establish an open cycle gas turbine (OCGT) facility within the grounds of the existing Munmorah Power Station, to supply electricity during peak demand periods. The facility will contain four electricity generators driven by four open cycle gas turbines. The gas will be supplied to the turbines via a new lateral gas pipeline, branching from the existing Sydney-Newcastle natural gas pipeline.

The lateral pipeline will be about 7km long from the off-take point, to the gas turbine facility and will be constructed primarily underground along an existing power line corridor.

Delta Electricity has commissioned Parsons Brinckerhoff Australia Pty Ltd. to prepare the Environmental Assessment (EA) of the proposed development. Parsons Brinckerhoff has in turn commissioned Kellogg Brown and Root Pty Ltd. (KBR) to undertake a Preliminary Hazard Analysis (PHA) of the pipeline and associated facilities to establish if the proposed design meets the required level of safety for land use safety planning purposes.

The designs of the pipeline and gas turbine facility are in the concept design phase and have not been finalised. Therefore, a Preliminary Hazard Analysis has been carried out at this stage based on the concept designs provided. The risk assessment, contained in this report is therefore expected to be updated and finalised once the final detailed designs are available.

This report summarises the objectives, scope of work, methodology and results of the preliminary risk assessment.

1.2 OBJECTIVES AND SCOPE OF THE PRELIMINARY HAZARD ANALYSIS

1.2.1 Objectives

The objective of the study is to conduct a PHA of the proposed pipeline, compressor stations and open cycle gas turbine facility. It includes:

- Consideration of inherently safe design principles and identification of areas where the pipeline (and facilities) design can be further enhanced.
- Preparing a PHA of the pipeline, compressors, turbines and diesel storage in accordance with Hazardous Industry Planning Advisory Paper (HIPAP) No. 6, "Hazard Analysis Guidelines", issued by DIPNR (Ref. 1). Where possible, a Quantitative Risk Assessment (QRA) has been carried out.

At a low level, the objectives are to:

- Identification of whether the proposed design measures and operational measures are adequate to minimise the hazard and manage residual risks.
- Identification of additional safeguards to further minimise the risk to personnel, people and property, where appropriate.
- Preparation of a comprehensive report summarising the Preliminary Hazard Analysis and recommendations to form an appendix to the EIS.

At the PHA stage, it is not intended to undertake a risk assessment of the pipeline based on AS2885-1997 (Ref. 2). This is expected to be carried out in the next stage of the project, as part of the detailed pipeline design phase.

1.3 STUDY SCOPE

1.3.1 Physical Systems

The scope of work for the PHA includes the pipeline and associated operating equipment.

- Lateral gas pipeline from Sydney-Newcastle gas pipeline takeoff point to gas turbine facility at Munmorah Power Station. This is a 7km underground pipeline;
- Compressor station at the takeoff point;
- Compressor station at the power station. This may operate intermittently, depending on the received gas pressure, to boost the pressure to turbine intake pressure;
- Gas receival station and gas supply to gas turbines;
- Open cycle gas turbines;
- Diesel storage and associated equipment; and
- Associated controls and instrumentation.

1.3.2 Components of PHA

The PHA consists of the following components.

- Hazard dentification and evaluation of safeguards.
- Development of gas release scenarios and hazard consequence analysis.
- Frequency assessment of pipeline releases.
- Qualitative risk assessment of risk for compressor and turbine stations.
- Qualitative risk assessment of diesel storage tank.
- Risk Quantification of pipeline risks in the form of risk transects.
- Risk evaluation against risk criteria in HIPAP No. 4 (Ref. 3).

2 Summary of Results

2.1 GENERAL

The Preliminary Hazard Analysis (PHA) of the proposed natural gas pipeline and associated power generation facilities was undertaken by KBR's Safety Engineering and Risk Management Group, with input from Parsons Brinckerhoff Australia Pty Ltd.

The risk assessment must be viewed as preliminary. Changes in the design and development of operational procedures may result in the updated risk levels being different to those assessed herein. Since the final design and operating procedures were not available at the time of this report, it is recommended this report be reviewed and updated at a later stage.

The risk assessment consisted of two parts;

1. Qualitative risk assessment of gas compressor station, gas supply to turbines and diesel storage; and
2. Quantitative risk assessment of the natural gas pipeline.

2.2 HAZARD IDENTIFICATION

2.2.1 Hazard Identification Results

The hazard identification was conducted by KBR personnel to identify potential hazards arising from the lateral pipeline, compressor station, gas supply to turbines, open cycle gas turbines and diesel storage. The mode of failure for each hazard was identified, as well as the consequences of the failure. In addition, safeguards that may reduce the risk of each hazardous event have been identified. A compilation of the hazards is summarised in Table 6.1.

2.2.2 Pipeline, compressor station, delivery facility and gas turbines

The inherent hazards of the pipeline arise from the flammability of the natural gas, and the high pressure at which it is transmitted. The types of hazardous incidents which may occur, would all require a leak in the pipeline. They are:

- fire;
- flash fire; and
- gas cloud explosion.

The types of failure incident resulting in a leak reported by various overseas data sources include the following:

- external interference from heavy equipment (eg. digging the pipe up);
- scour damage (eg. river bed scouring, exposing and damaging pipes);
- subsidence damage (eg. banks and levees washing away, exposing and damaging pipes);
- external corrosion damage (eg. poor coating application and inadequate corrosion protection);
- internal corrosion damage;
- faulty material (eg. weaknesses in pipework from manufacturing defects);
- faulty construction (eg. poor welding, lack of weld testing);
- ground movement (eg. buckled pipework from excessive ground movement from earthquakes, slips and ground subsidence); and
- "hot tap" by error from incorrect pipe identification in a congested pipework location (eg. where two or more pipelines are buried which are parallel and in close proximity. This may not be applicable for this proposed development).

2.2.3 Diesel Storage

The inherent hazard of the diesel tank arises from the bulk combustible liquid storage. If a leak occurred and an ignition source was present a pool fire could result and potentially lead to escalation. Two forms of pool fire were identified;

- tank roof fire - resulting from flammable vapour in tank roof igniting; and
- pool fire - resulting from diesel leak into bund and igniting.

No risk contours were prepared for the diesel storage facility as the hazard consequence distances were fully contained within the site with no offsite effects. However, not all information was available and this may need to be re-considered once the design and operating procedures are finalised.

2.3 QRA RESULTS FOR PIPELINE

The hazard identification showed that the main issue of concern was pipeline releases resulting in jet fires and heat radiation impact. The potential causes of releases included:

- Scouring and erosion at creeks and drainage points.
- High vehicle loads on road crossings.
- Third party interference with the pipeline.
- External corrosion.
- Stress corrosion cracking.
- Weld/material defects.
- Ground movement and subsidence.
- Overpressure/over temperature.

Individual Risk Results for Pipeline

A risk transect showing the individual risk of fatality versus the transverse distance from the centreline of the pipe was developed. The risk transect is shown in Figure 2.1. The distance to the relevant risk criteria levels are summarised in Table 2.1.

Figure 2.1 Fatality Risk Transect of Pipeline

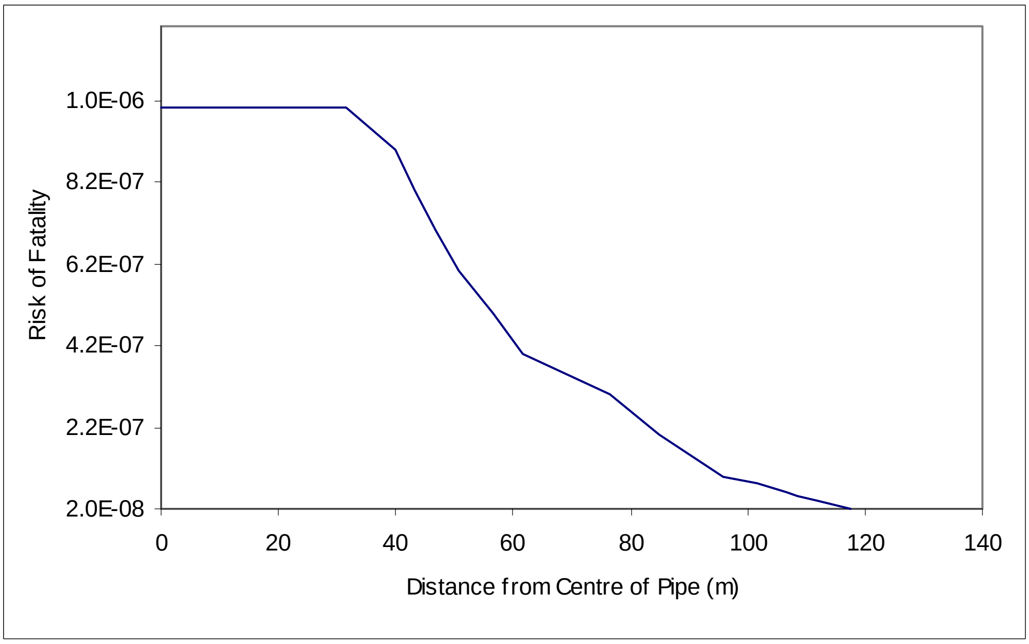


Table 2.1 Summary of Pipeline Risk Transect Results

Approximate Distance to Individual Risk of Fatality (m)				
0.5×10^{-6} per year (sensitive land use)	**1×10^{-6} per year (residential)**	**5×10^{-6} per year (commercial)**	**10×10^{-6} per year (Active Open Space)**	**50×10^{-6} per year (Industrial)**
57	32	Not Reached	Not Reached	Not Reached

The following conclusions were reached:

- The risk results satisfy the criteria in HIPAP No. 4 for surrounding land uses.
- Most of the risk is contained within the electricity power line corridor within which the pipeline is located.
- The 0.5×10^{-6} per year fatality risk does not reach the closest sensitive land use zone.
- The 1×10^{-6} per year fatality risk does not reach the closest residential land use zone.
- The fatality risk in the industrial zone is below 50×10^{-6} per year.

2.4 RISK ASSESSMENT FOR COMPRESSOR /GAS TURBINE ENCLOSURE

A qualitative risk assessment was undertaken for the compressor building and gas turbine enclosure. The main hazard associated with these facilities is a gas leak and build-up of flammable gas in a confined space with the potential to cause an explosion if ignited.

The gas turbine enclosure would be constantly cooled by ventilation air, with a significant number of air changes per hour.

A concept design for the compressor station is available (20m long by 20m wide and 8m high). For postulated leak sizes, the time taken to reach the lower flammability limit was calculated for various air change rates, using a lumped parameter gas mixing model. It was determined that in the event of a leak, the response time of gas detection equipment would be sufficient to initiate an emergency shutdown (ESD) automatically.

A similar calculation was not undertaken for the turbine building as the building is very large in size and a single ventilation fan would be insufficient. Based on the assumption that the turbines would be placed in individual ventilated enclosures, appropriate recommendations for hazard control have been made.

2.5 RECOMMENDATIONS

The following recommendations are made for process safety improvement. Many of the recommendations are repeated from the design safeguards already proposed by Delta Electricity, and listed here for completeness.

2.5.1 Pipeline

1. Marker tape and marker signs or marker tape and stones along the whole length of the pipeline in trenched sections;
2. Minimum depth of cover of 1000mm to top of pipe under the 133kV transmission lines with additional depth of cover (1200mm) / concrete slab protection where appropriate;
3. Minimum wall thickness of 19mm and increased wall thickness where appropriate;
4. Hydrostatic strength test at 1.25 times maximum allowable operating pressure;
5. Thrust-bored or directional drilled pipeline with 1.2m depth of cover at road, rail and driveway crossings and in compliance with authority requirements where relevant;
6. Weighting of pipe or directional drilling at selected creek crossings;
7. Full field inspection during pipeline construction;
8. Adequate erosion controls to minimise risk at creek crossings;
9. Grit blasting of the pipeline prior to application of anti-corrosion coating;
10. ‘Holiday’ detection of coating prior to burial;
11. 100% radiography of all circumferential welds;

12. Impressed current, auto potential controlled cathodic protection system;
13. Pipeline electrically isolated from underground and aboveground sections with insulating flanges. Earthing systems installed to provide personnel protection in accordance with AS 4853 in locations where the pipeline is installed in proximity with high voltage power lines;
14. Regular vehicle patrols of the pipeline corridor;
15. No free oxygen present in the natural gas;
16. Impressed current, auto potential controlled cathodic protection system;
17. Monitoring of pipeline operation and the impressed current protection via SCADA;
18. Stress relief where ground movement stresses the pipeline;
19. On going liaison with landholders of the easement; and
20. Intelligent pigging of the line on a regular basis.

2.5.2 Compressor station at pipeline offtake

21. An actuated isolation valve installed at the transmission pipeline offtake;
22. Installation of a cooler at outflow of compressor station;
23. Gas detectors installed at the ventilation exhaust of compressor room;
24. UV / IR detectors installed in the compressor room;
25. Actuated isolation valve and vent valve installed outside building (minimise leave sources within building);
26. Ventilation of the compressor building;
27. Gas detector installed in the ventilation flow exhaust duct to alarm at 25% LFL and shut down the station at 50% LFL;
28. Vegetation cleared around compressor station;
29. Control and communications equipment;
30. The pipework would be designed to comply with the requirements of Australian Standard AS4041 - Pressure piping;
31. High quality anti-corrosion coating on all metal fittings and pipes;
32. Regular inspection and maintenance of equipment;
33. Compressor station monitored by SCADA system;
34. Compressor station fenced to reduce the chance of unauthorised entry;
35. Any exposed pipes and equipment protected by impact barriers as appropriate;
36. Hazardous area classification in compressor building in compliance with AS 2430.1; and

37. Station piping, fencing and equipment will be properly earthed to discharge fault or induced voltages safely in the event of lightning strike.

2.5.3 Gas Receival facility at the Power Station

38. An actuated isolation valve installed at the inlet to the facility;
39. Minimum separation distance of 100m between the pipeline receival station and the OCGT peaking plant;
40. Anti-corrosion coating on all exposed fittings and pipework;
41. Inspection of all equipment prior and during installation and operation of equipment;
42. Gas filtration;
43. Gas heating to turbine intake temperature;
44. Overpressure protection provided by three methods;
    - Rapid control valve closure under alarm conditions;
    - Slam shut isolation valve installed at the inlet to each control valve run; and
    - Pressure relief valve.
45. Emergency or maintenance venting equipment;
46. Control and communications equipment; and
47. Any exposed pipes and equipment protected by impact barriers as appropriate.

2.5.4 Gas Turbines

48. Gas and fire detectors inside turbine enclosure;
49. Gas detectors in turbine enclosure ventilation exhaust;
50. Double block and bleed valves at gas inlet to turbine;
51. Turbine installation programmable electronic protection systems either TÜV certified or SIL assessed;
52. When the final design for the compressor station, delivery facility and the gas turbines is available a quantitative risk assessment should be completed; and
53. Calculate the minium number of air changes for the gas turbines when a design is available.

2.5.5 Diesel Storage

54. Designed in accordance with AS1940-2003 (bunding, fire protection, pipework, separation distances etc.);
55. Diesel Tank designed with API 650 - Welded Steel Tanks for Oil Storage;
56. Hot work permit enforced;

57. Product quality assured by supplier;
58. Portable foam;
59. Fire water monitors; and
60. Level alarm on tank or procedure to check stock level prior to reorder.

2.6 CONCLUSIONS

The following conclusions were reached in the risk assessment.

1. The risk from the pipeline meets the land use planning risk criteria of HIPAP No. 4 for all land uses.
2. The explosion risks for gas compressor or turbine enclosure is of the order of 10^{-6} p.a. and very low, due to a number of safe guards built into the design.
3. The fire risk from diesel storage is very low and on a consequence basis alone, there would be no offsite impact and no incident escalation on the site.

3 Description of Surrounding Land uses

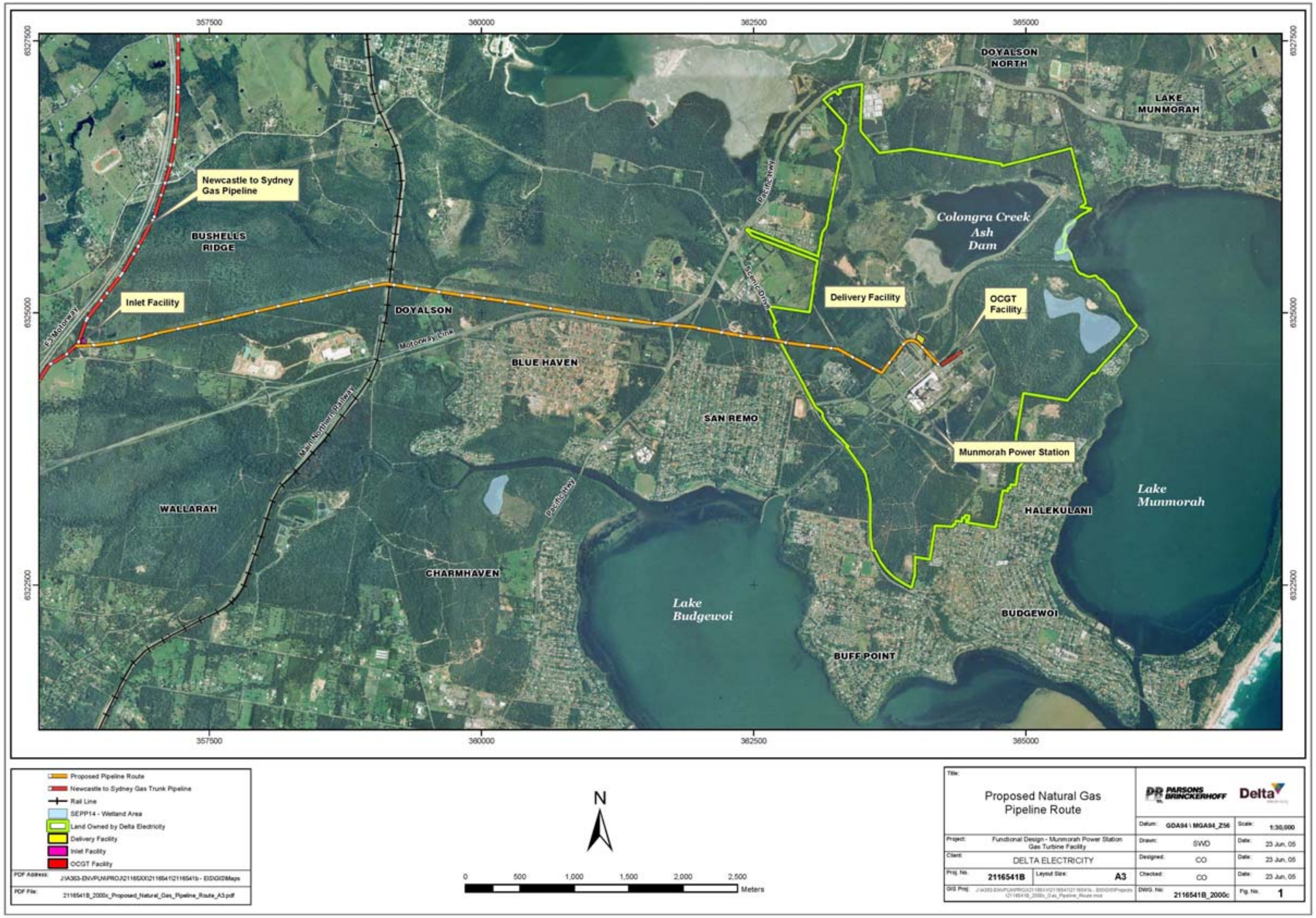
3.1 PIPELINE ROUTE

The proposed pipeline route is from an offtake on the main AGL Sydney-Newcastle natural gas pipeline to the gas turbine facility at Munmorah Power Station. The approximate distance of this route is about 7km. The route drawing is shown in Figure 3.1.

The proposed pipeline route runs as follows:

- From a proposed offtake and metering station at the Sydney-Newcastle natural gas pipeline about 7km west of the Munmorah Power Station.
- The pipeline runs underground in a north easterly direction along the southern edge of the existing 330kV Transgrid power line corridor and under-boring the Northern Railway line. This route is zoned as 4(e)-regional Industrial and Employment Development Zone.
- From the railway line the pipeline heads in a south easterly direction for about 2km in areas zoned as 10(a)-Investigation Precinct Zone and patchy areas of 7(g)-Wetlands Management Zone.
- At 100m and 400m along the pipeline from the railway line the pipe crosses two creeks.
- The pipeline continues for about 700m parallel to the Link Motorway until it under-bores the Link Motorway. It continues for another 300m before under-boring the Pacific Highway. These routes are zoned 5(a)-Special Uses Zone.
- After a further 900m the pipeline under-bores Scenic Drive before entering the land owned by Delta Electricity. All these areas are zoned 5(a).
- The pipeline continues for 700m before heading further south for 500m until it reaches Coal Plant Road within Munmorah Power Station.
- The pipeline runs parallel to Coal Plant Road in a north east direction and turning south east to the delivery facility.
- The pipeline is then extended above ground, across the inlet canal and onto the gas turbine facility, located north east of the main power station building.

Figure 3.1 Pipeline Route



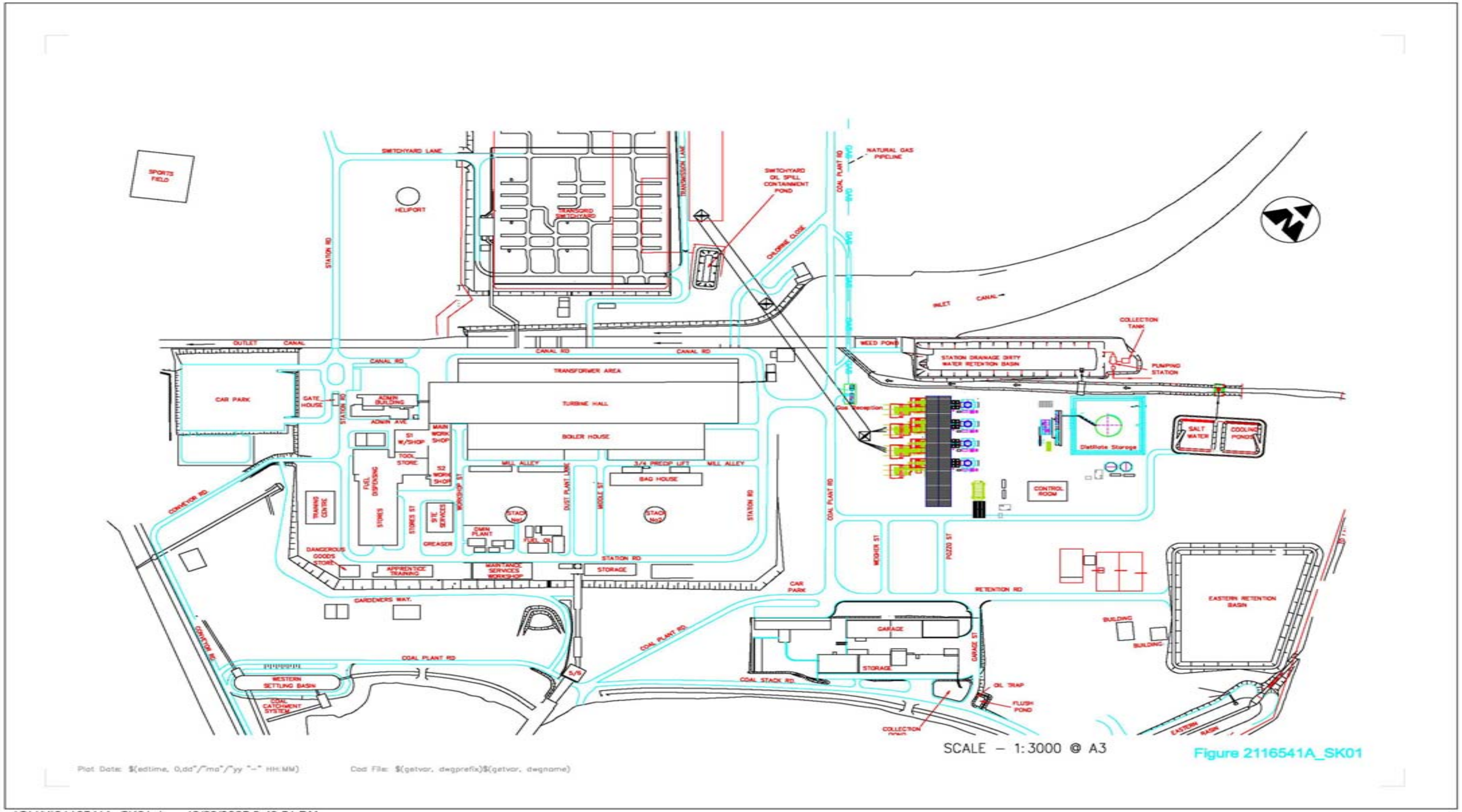
3.2 LOCATION OF GAS TURBINES AND DIESEL STORAGE FACILITY

The proposed gas turbine facility is located within the Munmorah Power Station site. It will be located 120m north east to the existing turbine hall and 40m west of the proposed control room.

The proposed 1.5ML diesel storage will also be located within the Munmorah Power Station site. It will be located 60m north of the proposed control room and 40m from the salt water/cooling ponds. Figure 3.2 is a map of Munmorah Power Station showing the location of the gas turbine facility and diesel storage in more detail.

Both facilities will be on land zoned 5(a) and subject to site security. The closest residential area is 1100m east of the facility.

Figure 3.2 Location of Gas Turbine Facility and Diesel Storage (Drawing Not to Scale)



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3.3 SUMMARY OF ZONES

The pipeline route enters the following zones;

- 4(e) - Regional Industrial and Employment Development Zone. Currently this area is only populated at Tooheys Road near the take off point.
- 5(a) - Special Uses Zone. This zone is also unpopulated. The closest residential area to the pipeline is 60m on the southern side of the pipe.
- 7(g) - Wetlands Management Zone.
- 10(a) - Investigation Precinct Zone.

The gas turbine facility and diesel storage are both located in zone 5(a). The closest residential area to the facilities is over 1100m to the east.

Along the route the pipeline crosses the following;

- Main Northern Railway;
- Spring Creek;
- Creek feeding into Spring Creek;
- Pacific Highway; and
- Scenic Drive.

3.4 SURROUNDING LAND USE CATEGORIES FOR PHA ASSESSMENT

3.4.1 Pipeline

The pipeline will pass near a range of land uses from residential to industrial. A review of the land use categories was undertaken to identify developments near the pipeline. Table 3.1 summarises the land use categories along the pipeline route. Table 3.2 shows the closest separation distance to each type of land use category.

Table 3.1 Land Use Categories near the Pipeline

Location	Description	Land Use Category	Closest Distance From Pipeline
Offtake point at F3 Motorway	Public Roads	Transport	100m
Tooheys Road, Bushells Ridge	Farmhouse	Residential	100m
Boral Montoro Boundary, Doyalson	Boral Montoro Pty Ltd.	Industrial	150m
Thompson Vale Road, Doyalson	Houses	Residential	60m
Crossing of Link Motorway	Public Roads	Transport	0m
Dryden Court and Old Pacific Hwy, San Remo	Houses	Residential	150m
Recreation Reserve	Parklands	Recreation	150m
Claridge Cr, San Remo	Houses	Residential	150m

Table 3.2 Summary of Closest Separation Distances to Land Use Categories for PIpeline

Land use	Nearest Land use	Distance to Nearest Land use
Transport	Public Roads	0m
Residential	Houses	60m
Industrial	Property of Boral Montoro	150m
Recreation	Parklands	150m

3.4.2 Gas Turbine and Diesel Storage Facility

The gas turbine and diesel storage facility are located in an industrial zone surrounded by lakes and residential areas.

Table 3.3 summarises the land use categories along the pipeline route. Table 3.4 summarises the closest distance to each type of land use category.

Table 3.3 Land Use Categories near the Proposed Facility

Location	Description	Land Use Category	Closest Distance From Pipeline
Scenic Drive	Public Roads	Transport	1100m
Macleay Drive	Public Roads	Transport	700m
Coal Stockpile	Munmorah Power Station	Industrial	300m
Highview Avenue, San Remo	Houses	Residential	1300m
Kalele Avenue, Halekulani	Houses	Residential	1100m
BMX Track, Halekulani	Sport Facility	Recreation	700m
Budgewoi Primary School	School	Sensitive	1800m

Table 3.4 Summary of Closest Separation Distances to Land Use Categories for Gas Turbine and Diesel Storage Facility

Land use	Nearest Land use	Distance to Nearest Land use
Transport	Public Roads	700m
Residential	Houses	1100m
Industrial	Property of Delta Electricty	0m
Recreation	BMX Track	700m
Sensitive	Budgewoi Primary School	1800m

4 Description of Proposed Development

4.1 NATURAL GAS COMPOSITION

The natural gas specification will depend on the source of gas, which may be natural gas from either Moomba or the Gippsland Basin. The fracture control plan (Ref. 4) summarises the specifications for the gas to be transported from these two sources (reproduced in Table 4.1 below).

Table 4.1 Design Composition of Natural Gas Sources

Component	Mole%	
	Moomba	Gippsland Basin
methane	94.2	91.87
ethane	2.0	4.74
propane	0.3	0.34
nitrogen	1.7	0.74
carbon dioxide	1.8	2.24
I-butane	0.0	0.02
N-butane	0.0	0.03
I-pentane	0.0	0.01
n-pentane	0.0	0.01
Specific Gravity	0.592	0.607
Gross Heating Value	37.2 MJ/Sm^3	38.27 MJ/Sm^3
Wobbe Index	48.35 MJ/Sm^3	48.35 MJ/Sm^3

4.2 PIPELINE DESCRIPTION AND SAFEGUARDS

The lateral pipeline will be designed to comply with the requirements of AS2885, Pipelines - Gas and liquid petroleum and made of API 5L Grade X70 steel. The pipeline has been designed to accept gas flows into the pipeline at a nominal continuos flow rate of 23,930 scm/h and to deliver gas at a rate of 176,600 scm/h at a nominal maximum pressure of 12 MPa up to the delivery facility where it will be reduced to a maximum of 5 MPa prior to use by the gas turbine facility. This can be achieved using a pipeline of diameter DN 1100 (1066 mm OD).

The proposed lateral pipeline will be designed and constructed with consideration of the following safeguards;

- Marker tape and marker signs or marker tape and stones along the whole length of the pipeline in trenched sections;

- Minimum depth of cover of 1000mm to top of pipe under the 330kV transmission lines with additional depth of cover (1200mm) and/or concrete slab protection where appropriate or necessary;
- Minimum wall thickness of 19mm and increased wall thickness where local conditions require;
- Hydrostatic strength tests will be carried out on all sections at 1.25 times maximum allowable operating pressure;
- Thrust-bored or directional drilled with a minimum 1200mm depth of cover at all road, rail crossings and in compliance with relevant authority requirements such as RTA and RailCorp;
- External coating of pipeline and 'holiday' detection of coating prior to burial;
- Impressed current, auto potential controlled cathodic protection system;
- Electrical isolation from underground and aboveground sections with insulating flanges. Earthing systems will be installed to provide personnel protection in accordance with AS 4853 in locations where the pipeline is installed in proximity with high voltage power lines;
- Periodic pigging for inspection and maintenance purposes; and
- Regular inspection by vehicle patrols.

Note that intermediate valve stations will not be necessary due to the relatively short pipeline length.

4.3 GAS FACILITIES

4.3.1 Compression Station at Pipeline Offtake

The compressor station will be located in close proximity to the F3 freeway and will be designed for remote, unattended operation. The following plant safeguards are proposed.

- An actuated isolation valve will be installed at the pipeline offtake point;
- Pipeline inlet isolation valve;
- Gas detectors will be installed at the ventilation exhaust of compressor room. The detection will alarm as 25% LFL and shut down the station at 50% LFL;
- UV / IR fire detectors will be installed inside the compressor room;
- Actuated isolation valve and vent valve installed outside building (minimise leak sources within building); and
- Control and communications equipment to provide remote monitoring and central control of system by operating staff.

An area of 50m x 50m has been estimated to accommodate the plant equipment and support an appropriate buffer separation distance between the facility and external receptors.

4.3.2 Gas Receival Facility at the Power Station

The gas receival facility will be constructed within the Munmorah Power Station site. The station pipework will be DN 400, with a pressure rating of ANSI Class 300 (5 MPa). The interconnecting pipe between the pressure regulating station and the gas turbine facility would be DN 450, to minimise pressure drop and provide capacity to absorb surge loads in the event of a plant trip. The following plant safeguards are proposed;

- Minimum separation distance of 100m between the pipeline receival station and the gas turbine facility;
- The pipework would be designed to comply with the requirements of Australian Standard AS4041 - Pressure piping;
- Overpressure protection will be provided by three methods:
    - Rapid control valve closure under alarm conditions;
    - Slam shut isolation valve installed at the inlet to each control valve run; and
    - Pressure relief valve.
- An actuated isolation valve will installed at the inlet to the facility; and
- Control and communications equipment to provide remote monitoring and central control of system by operating staff.

4.3.3 Gas Turbines

The current concept design of the gas turbine facility has been modelled on approximately 500 operating hours per year, of which up to 75 hours per year may be operated using diesel (back up for gas supply interruption). The facility would also respond to system emergency and system security needs, as required.

In the event of an interruption to the gas supply or a drop in the gas pressure below the operating limit set by the gas turbine manufacturer, the gas turbine will be capable of switching over to diesel firing in a short amount of time.

The gas turbine building is approximately 115m (L) x 20m (W) x 15m (H). It is expected that the building will have a common area for gas receival and separate enclosure for each turbine.

The final design and choice of manufacturer for the gas turbines has not been confirmed. Therefore, generic safeguards for gas turbines have been listed below and proposed for inclusion into the final design;

- Gas detectors inside turbine enclosure;
- Gas detectors in turbine enclosure ventilation exhaust;
- Fire detectors inside turbine enclosure;
- Double block and bleed valves at gas inlet to turbines; and

- Programmable logic controller (PLC) used for safety instrumented systems would be either TÜV certified or SIL (Safety Integrity Level) assessed, to provide required reliability.

4.4 DIESEL STORAGE AND ASSOCIATED EQUIPMENT

1.5ML of diesel storage has been allocated for the gas turbine facility. Diesel fuel would only be used when there is an interruption to the natural gas supply or gas supply is drawn down to the point where there is insufficient gas to cover the peak period or system emergency shut down. The diesel storage tank will be provided with the following safeguards:

- Designed in accordance with AS1940-2003 (bunding, fire protection, pipework, separation distances etc.); and
- Diesel Tank designed with API 650 - Welded Steel Tanks for Oil Storage.

5 Methodology

5.1 GENERAL

This risk assessment is carried out in accordance with HIPAP No.6 - Guidelines for Hazard Analysis (Ref. 1). The analysis of risk has included both qualitative and quantitative assessments.

5.2 QUALITATIVE ASSESSMENT

In the absence of design details and Piping & Instrumentation Diagrams (P&ID), the following facilities have been assessed qualitatively:

- Offtake compressor station (semi-quantitative);
- Gas receival station; and
- Turbine gas supply system.

5.3 QUANTITATIVE ASSESSMENT

5.3.1 General

Quantitative analysis, as distinct from qualitative analysis, assesses the risk numerically. It involves hazard identification, consequence analysis, frequency analysis, and risk assessment. This method was applied to the lateral natural gas pipeline of the proposed development.

5.3.2 Hazard Identification

This involves the identification of initiating events which could lead to hazardous incidents and assessment of their possible implications. It determines which events and incidents should be considered in detail. A comprehensive analysis of initiating events, and the consequences and effectiveness of the accident prevention/protection system was conducted. This analysis is summarised in Section 6 and in a Hazard Identification Table (Table 6.1).

5.3.3 Hazard Consequence Analysis

This is the estimation and examination of potential consequences from identified events in terms of the physical effects such as heat radiation on people. The consequence analysis was carried out to determine the effect distances of specific incident scenarios defined in the hazard identification.

The analysis for gas releases involved:

- The estimation of pipeline hole size from an initiating incident;
- Natural gas release rate;
- Jet fire magnitude upon immediate ignition (including heat radiation effects); and
- Qualitative discussion on the effects to the surrounding land uses.

The analysis for diesel storage facility involved:

- Consequence analysis of heat radiation from bund fires and roof fire. The risk impact is discussed qualitatively.

The following software was used to complete this analysis:

- Shell FRED 4.2 was used for jet fire calculations; and
- PHAST 6.4 for gas dispersion calculations.

5.3.4 Frequency Analysis

Pipeline failure frequencies were estimated using generic databases for cross-country gas pipelines. There are two main sources available:

- British Gas Data
- European Gas Pipeline Incident Data Group (EGPIDG)

The European database was used because the British Gas Data focused on pipe rupture rather than pipe leaks.

5.3.5 Risk Assessment

For transport of natural gas via pipeline, the source of risk is linear because a release can occur anywhere along the pipeline. The incident frequency was obtained from historical data as incidents per metre. The release frequency for incidents was calculated as follows;

Release /year/segment = (pipeline incident/m-year) x (m/pipeline segment)

A graph showing the risk against transverse distance from the pipeline, known as a risk transect was also produced. The risk transect expresses peak individual fatality risk along a line perpendicular to the pipeline.

Linear risk and risk transect were calculated for three different release sizes by combining the results of the consequence analysis and the frequency analysis to produce a linear risk result. Risk calculations were made using the software TNO Risk Curve (Ref. 5). The quantified risk result was compared with the appropriate risk criteria.

The risk from the diesel storage is discussed in Section 9.

5.3.6 Risk Criteria

The target risk criteria used in this assessment are those recommended by the NSW Department of Infrastructure, Planning and Natural Resources (DIPNR) in the Hazardous Industry Planning Advisory Paper No 4 (Ref. 3) and are shown below.

Table 5.1 Fatality Risk Criteria for Land Use Safety Planning

Land Use	Suggested Criteria (risk in a million per year)
Hospitals, schools, child care facilities, old age housing	0.5
Residential, hotels, motels, tourist resorts	1
Commercial development including retail centres, offices and entertainment centres	5
Sporting complexes and active open space	10
Industrial sites at the site boundary	50

6 Hazard Identification and Evaluation of Safeguards

6.1 GENERAL

A number of hazardous incidents were identified during the hazard identification stage of the study. The mode of failure for each hazard was identified, as well as the consequences of the failure. In addition, proposed safeguards which may reduce the risk of each hazardous event have been identified. They have been combined into a word diagram in Table 6.1.

Table 6.1 HAZID Identification and Evaluation of Safeguards

Event	Cause	Consequence	Protection or Safety Measure
Pipeline gas release leading to jet fire	General leaks	Continuing incident with heat radiation to surrounding land use	1. An easement is provided 2. Emergency Response Plan 3. Monitoring of pressure via SCADA system
Pipeline pinhole, hole/rupture leading to gas release	1.External Damage from 3rd party interference	Gas release leading to jet fire.	Protection against External Damage: -Sign posting; - Pipeline markers above ground in line of sight; - Regular pipeline patrols; - Ongoing liaison with Landholders; - Greater pipeline wall thicknesses and depths of cover in selected locations; -Buried marker tape along entire length of pipeline.
	2. Corrosion: - internal - external - stress corrosion cracking - high voltage (AC) transmission lines closely parallel to the pipeline, resulting in stray currents and increased corrosion.	Gas release leading to jet fire.	Protection against corrosion: - High quality external anti-corrosion coating; - Grit blasting of the pipeline prior to application of corrosion protective coating; - Detection of coating defects, prior to lowering-in, by ‘holiday’ detectors (an electronic device for detecting gaps or ‘holidays’ or pinholes in pipe coating); - No free oxygen present in the natural gas; - Impressed current, auto potential controlled cathodic protection system; - Pipeline electrically isolated from underground and above ground facilities by insulating flanges; - Monitoring of the impressed current protection via SCADA; - Intelligent pigging of the line on a regular basis to monitor pipeline thickness;

Event	Cause	Consequence	Protection or Safety Measure
	3.Ground movement	Gas release leading to jet fire.	- Inherent flexibility and strength of gas transmission pipelines; - No known ground slip areas; - Regular pipeline patrols; - Relieving of stress where ground movement stresses the pipeline; - Subsidence issues taken into account in pipeline design.
	4.Construction and material defects	Gas release leading to jet fire.	Construction and Material defects protection: - 100% radiography of all circumferential welds; - Hydro test to 1.25 Maximum Allowable Operating Pressure; - Full field inspection during pipeline construction.
	5.Flood scour damage	Gas release leading to jet fire.	Flood scour damage protection: - Weighting of pipe at selected creek crossings; - Use of 60% SMYS pipe at selected creek crossings; - 1.2m depth of cover at creek crossings.
	6.Sabotage	Gas release leading to jet fires.	Sabotage damage protection: - Pipeline buried the full length; - Security fences around all above ground installations; - Location of above ground facilities generally away from population centres.
	7.Bushfire / grassfire	Damage to compressor station leading to pipeline failure and gas release.	Bushfire/grassfire protection: - vegetation cleared around compressor station; - Gravel or hardstand area inside the fenced site.
Compressor Station small, medium and large leaks	1. Corrosion of gas meter and equipment	1. Gas release leading to jet fire 2. Explosion potential in compressor building	Protection against corrosion: - High quality anti-corrosion coating on all metal fittings and pipes; - Regular inspection and maintenance of equipment;

Event	Cause	Consequence	Protection or Safety Measure
	2. Impact / Vibration and failure of small bore fittings	1. Gas release leading to jet fire 2. Explosion potential in compressor building	Protection against External Damage: - No fitting equipment used inside building once installed - Impact barrier where appropriate - Gas detection
	3. Sabotage	1. Gas release leading to jet fire 2. Explosion potential in compressor building	Sabotage damage protection: - Security fence around compressor station to reduce the chance of unauthorised entry - Door security alarms on compressor building - Locked security gates - Door alarm on SCADA
	4. Lightning Strike	1. Gas release leading to jet fire 2. Explosion potential in compressor building	Escalation protection from lightning strike: - Station piping, fencing and equipment will be properly earthed to discharge fault or induced voltages safely in the event of lightning strike
	5. Hole in gas pipework, valves, gland leak & flange gasket leak (including flanges); 6. Leaks in compressor seals, casing; 7. Pinholes, holes in gas cooler.	1. Gas release leading to jet fire 2. Explosion potential in compressor building	Leak detection and protection: - Gas and fire detectors, alarms and auto-shut down of compressor station in the event of gas and fire detection. - Compressor station monitored by SCADA system. - Ventilation of the compressor building and alarm to indicate ventilation failure - Gas detector in ventilation exhaust and compressor trip - Hazardous area classification in compressor building in compliance with AS 2430.1
Gas receival station (within Munmorah Power Station)	1. Impact 2. Corrosion 3. Small bore fitting failure 4. Flange gasket leak 5. Valve gland leaks	1. Gas release leading to jet fire 2. Explosion potential in compressor building	Impact protection: - Equipment located on Delta Electricity property, subject to site security Corrosion protection: - High quality anti-corrosion coating

Event	Cause	Consequence	Protection or Safety Measure
			Leak detection and protection: - Overpressure protection - Compliance with AS 2430.3.4 - 2004 - Inspection of all equipment prior and during installation - Regular inspection and maintenance of equipment during operation of equipment - ESD valve at the inlet to the receival station
Gas turbine facility leaks	1. Corrosion 2. Small bore fitting failure 3. Flange gasket leak 4. Valve gland leaks	1. Gas release leading to jet fire 2. Explosion potential in gas turbine enclosure	- Gas detectors inside turbine enclosure - Gas detectors in turbine enclosure ventilation exhaust - Fire detectors inside turbine enclosure - Double block and bleed valves to gas inlet to turbine - Turbine installation safety systems PLC either TÜV certified or SIL assessed to required reliability level. - Number of air changes per hour by ventilation fan in enclosure to prevent accumulation of potential gas leaks.
Diesel tank fire	1. Hot work 2. Pump overheating 3. Incorrect product specification 4. Tank overfill	1. Tank roof fire 2. Bund fire	- Hot work permit enforced - Product quality assured by supplier - Portable foam - Fire water monitors - Level alarm on tank or procedure to check stock level prior to reorder

7 Hazard Consequence Analysis

7.1 GAS RELEASE INCIDENTS

The hazard identification of Section 6 indicates that there are no hazardous incidents unless gas is released from the pipeline or equipment and ignited. The potential for release can occur from three release scenarios:

1. Pinholes or small holes, from corrosion, construction/material defects in the pipe itself, valves, compressor station equipment, delivery station equipment or OCGT peaking plant;
2. Medium holes or punctures in the pipeline as a result of external damage, subsidence/ earthquake damage or scouring damage; and
3. Large leak from the pipeline as a result of external damage, subsidence/ earthquake damage or scouring damage.

The majority of small leaks (pinholes and small holes) are in the order of less than 10mm diameter and are caused by girth weld defects and fractures of small attachments (Townsend and Fearnehough, Ref. 6). Townsend and Fearnehough also indicate that small leaks from pinholes and small holes (<10mm diameter) do not generally constitute a hazard.

Hole sizes range from 20mm to 80mm in diameter are predominantly caused by punctures from external interference. A statistical analysis of the mean hole size for puncture events indicated 40mm, which was the average hole size for punctures (Fearnehough, Ref. 7).

The reasoning behind choosing a 100mm hole instead of a pipe rupture scenario is explained in more detail in section 8.1.

Based on this data we have selected the following hole sizes for release incidents:

- 10mm diameter for pinholes and small holes (pinholes will be included in the assessment for conservatism considering the comment by Townsend and Fearnehough, Ref. 6);
- 50mm for medium holes (selected for conservatism over the 40mm average hole size determined by Fearnehough, Ref. 7);
- 100mm for large holes (selected to represent a large leak scenario and a pipe rupture).

7.1.1 Release Rates and Jet Fire Effects

Table 7.1 presents the above release scenarios. The flame length is taken at an angle of 45° and 90° to the pipeline. These results were calculated at a stability weather class of D - Neutral and wind speed of 1.5m/s.

Table 7.1 Release Rates and Flame Length for Varying Sizes of Ignited Release

Hole Size (mm)	Pressure (MPa)	Initial Release Rate (kg/s)	Distance to LFL (m)	Flame Length (m)
10	12	1.4	7.0	14 (45°)
10	12	1.4	0.6	12 (90°)
50	12	34.4	32	58 (45°)
50	12	34.4	3.1	52 (90°)
100	12	137.5	63	107 (45°)
100	12	137.5	6.5	90 (90°)

The maximum design pressure is 12 MPa. However the operating pressure is expected to be approximately 5 MPa, and the pressure is regulated to 3 MPa at the gas turbine inlet. Therefore, the consequence modelling based on 12 MPa is conservative.

7.2 HEAT RADIATION EFFECTS

7.2.1 Methodology

An ignited jet fire, from a release of gas from the proposed pipeline, will burn with high intensity due to the high pressure and velocity of the release. People close to the flame may be severely injured or killed from the heat radiated from the flame. However, this is dependent on the distance of the “target” from the flame itself and the duration of exposure. A probit correlation has been developed to describe the relationship (Lees, Ref. 8). A probit is an expression or function that determines the probability of fatality for exposure to a hazardous event. For an unprotected person, the probit equation for exposure to heat radiation is given as:

Pr = -36.38 + 2.56 ln (tI4/3)

Where: t= time of exposure, seconds

I= intensity of exposure (related to distance from flame), kW/m2

Based on 60 second exposure duration to an unprotected person, the following probabilities of fatality relating to heat radiation exposure to an exposed person were set.

Table 7.2 Probability of Fatality for Exposure to heat Radiation from Fires

Fire Heat Radiation Intensity (kW/m2)	Probability of Fatality
4.7	very low, mainly burn injury
6	10%
10	50%
14	100%

The analysis based on the above rule set is conservative as most people would be protected by clothing, hence, a probit constant of -37.23 would be used for this case instead of -36.38.

The orientation of the jet flame is also important in determining the effects on targets. A vertical flame will have a much lesser effect than a horizontal flame (of the same magnitude) pointing directly at the target. As the pipeline is buried, it is unlikely that the flame would be horizontal. A horizontal jet would be highly likely to scour the ground and be forced upwards, initially vertical and later becoming more horizontal, but at a lower flow rate. Hence, the jet fire direction was modelled at 45° and 90°.

7.2.2 Results

The distances to the heat radiation levels (shown in Table 7.3 below) for each of the release scenarios were estimated using the Shell FRED software (Ref. 9).

Table 7.3 Distances to Heat Radiation Levels of Interest

		Distance to Heat Radiation Level (m)		
	Heat Radiation Intensity	**6 kW/m^2**	**10 kW/m^2**	**14 kW/m^2**
Process Pressure	**Probability of fatality**	**10%**	**50%**	**100%**
MPa	**Incident**			
12	10mm Hole (45°)	16	14	12
12	50mm Hole (45°)	68	55	44
12	100mm Hole (45°)	129	102	82
12	10mm Hole (90°)	9	6	4
12	50mm Hole (90°)	37	19	1
12	100mm Hole (90°)	72	38	1

The nearest residential area is 60m away from the pipeline, see Table 3.2. Therefore small leaks ≤ 50mm would have no impact on these areas. Large jet fires would have an impact, but the risk of the events is very low as described in section 8.

7.3 EXPLOSION SCENARIO IN BUILDINGS

In the event that a gas release occurs in the offtake gas compressor building or the gas turbine enclosure (at the Power Station) and does not immediately ignite, there is a potential for a confined gas cloud to build up inside the confined volume. If ignited some time after the release, it is possible that the confined gas cloud may explode, causing significant equipment damage. These buildings are normally unmanned, but people in the vicinity maybe affected by the debris.

For a gas explosion to occur the following should be present:

- Gas release;
- Ventilation failure;
- Gas detection and ESD failure; and
- Ignition source.

If a release has reached a concentration of greater than UFL inside the enclosure, it is unlikely that ignition would occur. The UFL was calculated as 16.7% for the mixture composition in Table 4.1, using the Le Chatelier principle.

Since the blast effects from a confined vented explosion is due to pressure rise from combustion rather than deflagration resulting in a flame front acceleration, open air vapour cloud explosion models are not appropriate.

7.3.1 Compressor Building at Later Pipeline Offtake

The estimated compressor unit building (at pipeline offtake) dimensions are 20m long by 20m wide by 8m high, giving a volume of 3200m^3. Assuming the room is filled with equipment to 30% of the volume, the free volume is 2240m^3.

The explosion potential was analysed using a first order gas accumulation model. The concentration of natural gas in the room at any time following the release is given by:

$$C = \frac{m}{v_a}[1 - \exp(-\frac{v_a}{V}t)]$$

Where: C = concentration (kg/m^3)

m = release rate (kg/s)

ν_a= ventilation air flow (m^3/s)

V = volume of room (m^3)

t = time

For a large t, the maximum concentration in the room is:

$$C = \frac{m}{v_a} kg / m^3$$

For various ventilation rates, the time to reach LFL was calculated for 10mm and 20mm leaks.

$$Ventilation\ rate\ \left(m^3/s\right) = \frac{No.\ of\ air\ changes/hour}{3600\,\text{sec} \times V \times Fraction\ not\ occupied\left(0.7\right)}$$

Table 7.4 Air Changes to Prevent Explosion in Compressor Building

Hole Size (mm)	Release Rate (kg/s)	No. of air changes/hour	Time to reach LFL (sec)
10	1.38	10	82
10	1.38	20	83
20	5.50	10	20
20	5.50	20	21

A response time of 70-80 seconds is reasonable for the gas detector and ESD. Hence an air change rate of 10-20 per hour appears appropriate for a 10mm leak. Optimising the ventilation rate for design would depend on the design target risk criterion selected, once detailed design is developed.

In order to protect the compressor itself, it is recommended that a gas detector be installed in the ventilation flow exhaust duct, to alarm at 25% LFL and shut down the station at 50% LFL.

7.3.2 Turbine Enclosures

The approximate dimensions of the gas turbine enclosure are 115m long by 20m wide by 15m high, giving a volume of 34,500m^3. Assuming the room is filled with equipment to 30% of the volume, the free volume is 24,150m^3.

Turbines generate significant heat and hence the turbine enclosures would be cooled by ventilation air, with significant number of air changes per hour. Given the large size of the turbine building, it is unlikely that a single ventilation fan will be used for the building as a whole. The turbines are expected to be placed in individual enclosures with dedicated ventilation fans.

Prevention of explosion is achieved as follows:

- Ventilation fan for each turbine enclosure giving sufficient air changes to prevent gas accumulation;
- Gas detector installed in the ventilation flow exhaust duct, to alarm at 25% LFL and shut down the turbine at 50% LFL; and
- Air intake from an area away from gas vent points.

7.4 TANK FIRE SCENARIOS

A 1.5ML diesel storage facility is proposed for the OCGT peaking plant. The tank needs to be designed to AS 1940-2004 and placed at a safe distance from operating equipment to prevent escalation of hazardous events. Preliminary designs have been based on a diameter of 20m and height of 5m.

Hazardous events, such as pool fires occur when a diesel spill ignites. Previous experience demonstrates that pipework and pumps exposed to a strong fire in a bund will fail, leading to fire escalation.

Two different scenarios involving a diesel fire were analysed. The distances from the centre of the flames to 6 kW/m^2, 10 kW/m^2 and 14 kW/m^2 downwind of the fire were calculated.

7.4.1 Diesel Tank Roof Fire

Flammable diesel vapours can build up in the roof of a tank if the tank does not have a floating roof or the floating roof fails. When the LFL is reached and an ignition source is present a roof fire can occur. A tank of 20m in diameter and 5m high can hold 1.5ML of diesel. This tank was modelled and the heat radiation results are presented in Table 7.5.

Table 7.5 Tank Roof Fire Results

Distance to Heat Radiation Level (m) at 2m height		
6 kW/m^2	**10 kW/m^2**	**14 kW/m^2**
25.8	Not reached	Not reached

Heat radiation levels of 10 kW/m^2 and 14 kW/m^2 were not reached at a contour height of 2m from ground level, due to the shielding effect of the tank wall. Since there is no major equipment or building within 25m from tank centre, the risk impact from a potential fire on surrounding areas is very low.

There are no known sources of ignition at the top of the tank. Lightning is insufficient to cause ignition as diesel does not generate flammable vapours. One possible ignition source is hot work at roof level, but the necessity for this activity is extremely remote.

7.4.2 Diesel Bund Fire

A pool fire is caused by the release of diesel, which fails to ignite immediately upon release. Delayed ignition allows the diesel to accumulate, hence forming a pool of liquid. A circular bund of 62m in diameter was assumed. It is capable of containing 1.5ML of diesel. A worst case scenario of the bund containing the entire contents of the tank was modelled with Shell FRED. The heat radiation results are summarised below in Table 7.6.

Table 7.6 Pool Fire Results

Distance to Heat Radiation Level (m) at 2m height		
6 kW/m^2	**10 kW/m^2**	**14 kW/m^2**
68.5	49.3	38.6

The chance of ignition of the spill is low as the flash point of diesel is >61°C, and there is little or no flammable vapour generation. Hot work in the bund at the time of leak may cause ignition, but the need for this is rare, and any hot work is subject to the hot work permit system.

A leak from the pump (eg. leak from a seal or failure of pump) or failure of piping in the bund may lead to a small bund fire if ignited. The diameter of this pool fire will decrease until the burn rate equals the leak rate. The pool fire diameter will be much smaller than the bund diameter with a, consequently, less consequence distance.

It is unclear what sort of pump will be provided to transfer diesel to the turbine and at what pressure, flow rate and fraction of time the pump will be used. Similarly the piping details are also unknown. Therefore, pool fires in the bund, as a result of pump or pipe leak, has not been modelled. The consequence would be less than that shown in Table 7.6.

8 Frequency Assessment

8.1 PIPELINE RELEASE INCIDENTS

The consequence analysis was based on three hole sizes, 10mm (small), 50mm (medium) and 100mm (large, rupture case). This section describes the assessment of pipeline failure frequencies for the three hole sizes.

8.2 FREQUENCY OF PIPELINE RUPTURE

Townsend and Fearnehough (Ref. 6) of the British Gas Corporation Engineering Research Station investigated failures in the British Gas Corporation gas transmission pipeline system. Their data was collated from incidents in an extensive data collection scheme starting in 1969 through to the publication data of their paper in 1992. The collected data covered a length time period of 250,000 kilometre-years and included non-release incidents as well as release incidents. This latter inclusion makes the British Gas data base of incidents much larger and more statistically significant.

Fearnehough and Corder (Ref. 10) conducted further studies and updated the data of Townsend and Fearnehough. An important fact from these reports is that the overall rupture failure frequency in the British Gas System is less than 4×10^{-6} per km-year. Townsend and Fearnehough also performed a theoretical prediction of failure rates from fracture mechanics to statistically predict rupture rates from the collected data for non-release mechanical interference events. Their results, for rural areas, showed that for plain defects (gouges alone) the predicted rupture failure frequency was 2.2×10^{-6} per km-year, and for combined defects (gouges, dents and cracks) the predicted rupture failure frequency was 3.2×10^{-6} per km-year. These failure rates are commensurate with the actual historical data for rupture failures noted above.

The frequency of a jet fire resulting from a rupture is calculated by multiplying the rupture failure frequency by the probability of ignition for a rupture;

Jet fire Frequency = (3.2×10^{-9} per metre-year) x (0.3) = 9.6×10^{-10} per metre-year

The frequency is much less than 1×10^{-6} p.a. and considered negligible.

The European Gas Pipeline Incident Data Group (EGPIDG) collated a set of data from a number of European gas pipeline operators, from a number of different countries, including;

- British Gas PLC;
- N.V. Distragas SA;
- Gaz de France;
- N.V. Nederlandse Gasunie;

- Ruhrgas AG; and
- SNAM S.p.A.

The EGPIDG data from 1992 (Ref. 11) relates to gas transmission pipelines and covers a length-time period of 1,470,000 kilometre-years.

The EGPIDG data has recorded failure frequencies with respect to pipe thickness for two different hole sizes (pinhole and holes) as shown in Figure 8.1 and Figure 8.2. As pipe thickness increases the failure frequency decreases in both cases. No incidents are recorded for a pipe thickness of 19mm. Thus a rupture from the Munmorah pipeline is considered negligible.

Figure 8.1 Pipe wall Thickness vs. Failure Frequency for Pinholes (EGPIDG Data, 1992)

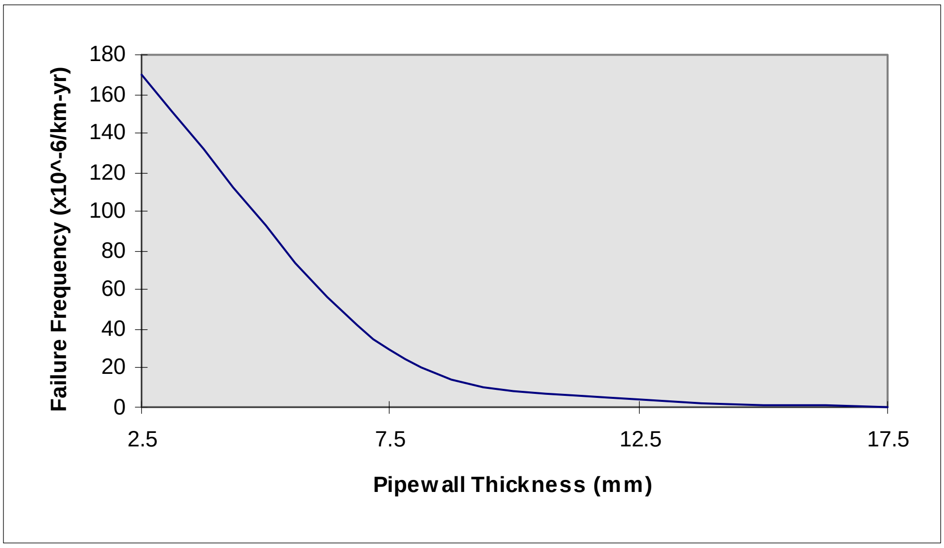
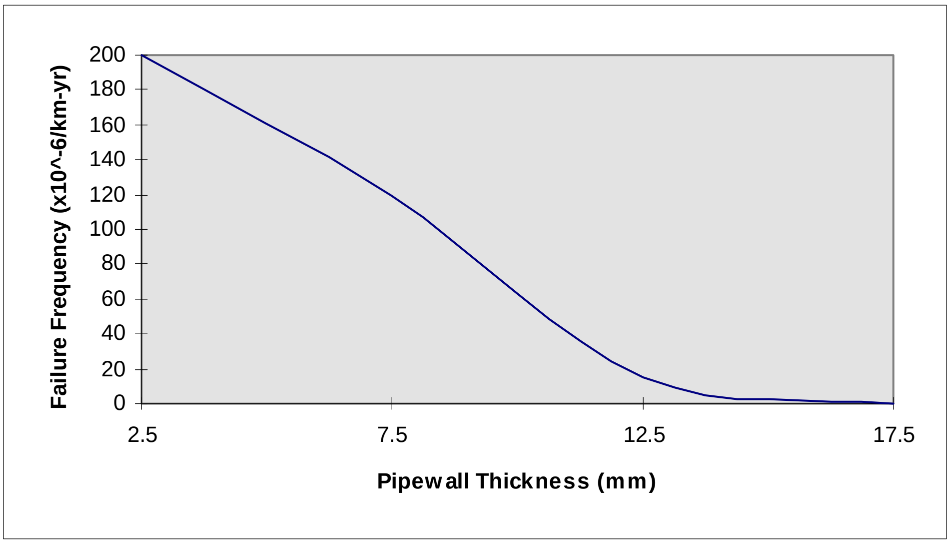


Figure 8.2 Pipe wall Thickness vs. Failure Frequency for Holes (EGPIDG Data, 1992)



A rupture incident of a pipe 1100mm in diameter and 19mm thick has not been recorded in Europe since 1970, however this does not mean it would not happen. The proposed pipe has a high resistance to crack propagation reducing the chance of the pipe propagating to a full bore rupture. Based on this, the location of the pipeline (reduced likelihood of external damage by excavating equipment) and the proposed risk mitigation measures, a full bore rupture has not been considered. A large hole diameter of 100mm was chosen as a conservative approach to a rupture scenario.

8.3 PIPELINE FAILURE FREQUENCY

Several data sources are available for the selection of leak data for onshore pipelines. However, some data are now obsolete and may not be representative, as pipeline technology has improved and there are more stringent operating procedures in place.

The total experience of European pipelines is quite large in comparison with Australian pipelines and, therefore, data sources for average failure frequencies are readily available.

Conservation of Clean Air and Water in Europe (CONCAWE) (Ref. 12) have reported leaks from European oil and liquid-hydrocarbon lines. The data is for pipelines installed in recent decades and reflects a high level of safety management, which makes it applicable to Australian pipelines. Additionally, European underground pipelines are more congested and population densities are much higher than in Australia, thus making the European data conservative when used for Australian pipelines.

The analysis covered the 10-year (1991- 2001) operation of approximately 104,000 km of pipelines. The report results showed 245 incidents over 1,035,000 pipeline-kilometre years, giving a leak frequency of 1 in every 4,200 km-years, or, 2.38×10^{-7} leaks per metre-year.

The CONCAWE data did not provide details on hole size distribution. Therefore, the European Gas Pipeline Incident Data Group (EGPIDG) gas pipelines data (Ref. 13) was sought, which gave the hole size distribution. There are no reported incidents for pipelines of 19mm thickness. 7mm was the average pipe thickness recorded in this document and, hence provides a conservative analysis of failure frequency of the proposed pipeline.

Table 8.1 Summary of Pipe Incidents Analysed

Leak Category	Representative Hole Size	Percentage of failures
Pinhole	< 10mm	16 %
Hole	10 mm - 100 mm	75 %
Large hole	100 mm	9 %

Therefore, the pipeline failure frequency, per hole-size category, was obtained by combining the CONCAWE pipeline failure frequency and the EGPIDG distribution:

1. Pinhole Leak Frequency = (2.38×10^{-7} per metre-year) x (0.16) = 3.81×10^{-8} per metre-year;

2. Hole Leak Frequency = (2.38×10^{-7} per metre-year) x (0.75) = 1.79×10^{-7} per metre-year; and

3. Large Hole Leak Frequency = (2.38×10^{-7} per metre-year) x (0.09) = 2.14×10^{-8} per metre-year.

8.4 PROBABILITY OF IGNITION - GAS RELEASE

Cox et al (Ref. 14), estimates the probability of ignition of leaks of flammable gas in plants (Table 8.2), which is considered applicable to aboveground facilities. In this case the pipe is underground and is assumed to have the same probability of ignition.

Table 8.2 Ignition Probabilities used in study

Leak size	Probability of Ignition
Minor (<1kg/s)	0.01
Major (>1kg/s but <50kg/s)	0.07
Massive (>50kg/s)	0.3

8.5 SUMMARY OF CALCULATIONS

The risk frequency data for gas release used to produce the risk curves is presented in Table 8.3.

Table 8.3 Fire frequency according to heat radiation levels

Heat Radiation Intensity	Leak frequency (m/year)	Ignition probability	General fire frequency (m/year)
10mm Hole	1.90×10^{-6}	0.01	1.90×10^{-8}
50mm Hole	8.93×10^{-6}	0.07	6.25×10^{-7}
100mm hole	1.07×10^{-6}	0.30	3.21×10^{-7}

9 Risk Assessment

9.1 INTRODUCTION

This section describes quantitative risk assessment (QRA) of the lateral pipeline. The lateral pipeline is the only section assessed quantitatively. All other system risks have been assessed either qualitatively or semi-quantitatively.

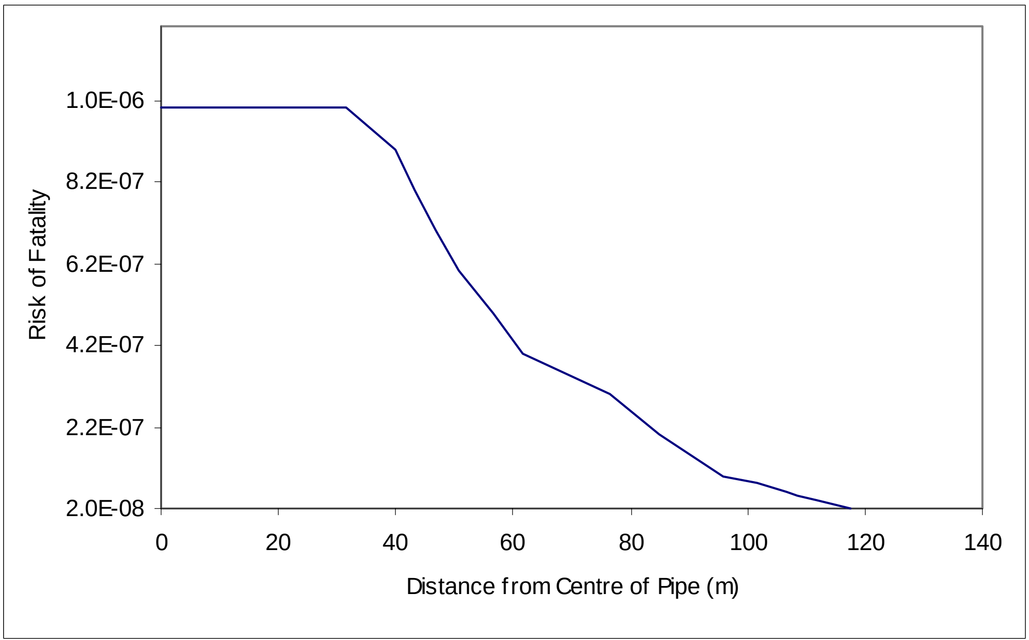
9.2 PIPELINE RISK

The risk from a gas pipeline is a "linear" risk, i.e. the risk follows the entire pipeline length, in contrast to a fixed hazardous facility, where the risk extends only to a limited distance from the facility. Thus the risk contours for a pipeline are represented as running parallel to the pipeline. Risk levels for linear risks are often presented in the form of risk transects, showing the risk at given transverse distances from the pipeline.

9.2.1 Individual Risk of Fatality

The consequence of all identified hazardous incidents from jet fires (Section 7) were combined with the estimated frequencies (Section 8) to assess the risks to surrounding land uses. The results of this assessment were plotted against the distance from the centreline of the pipeline to develop a set of risk transects. This transect applies for the entire length of pipeline sections with the relevant safeguards (pipe wall thickness, depth of cover). The risk transects were produced using the TNO program, *Riskcurves* (Ref. 5).

Figure 9.1 Fatality Risk Transect of Pipeline



9.3 COMPARISON WITH CRITERIA

This section describes the comparison of the calculated fatality risk levels with the suggested criteria. The risk criteria for comparison of the results are that of HIPAP No. 4. (Ref. 3, summarised in Table 5.1).

The individual risk levels posed by the pipeline and the distance from the pipeline to the relevant criteria levels specified by HIPAP No. 4 are summarised in Table 2.1. Table 9.1 summarises the results for gas release scenarios.

Table 9.1 Individual Fatality Risk - Gas Releases

Land Use	Distance to Risk Criteria	Distance to Land Use	Risk at Land Use
Sensitive land use	57 m	900 m	< Criteria
Residential	32 m	60 m	< Criteria
Commercial	Not Reached	> 1000 m	< Criteria
Active Open Space	Not Reached	60 m	< Criteria
Industrial	Not Reached	150 m	< Criteria

9.4 RISK OF GAS EXPLOSION IN CONFINED AREAS

In the absence of detailed design, the risk of gas explosion has not been assessed quantitatively. However, an indicative value may be derived as follows, assuming conservative failure probabilities:

Explosion frequency = (Gas release frequency within enclosure) x (ventilation fan failure probability) x (gas detection and ESD failure probability) x (ignition probability of accumulated gas).

Gas leak frequency = 10^{-3} p.a. (assuming 10 sources with failure frequencies ranging from 10^{-4} p.a. for flanges to 2 x 10^{-4} p.a. for valve glands)

Ventilation fan failure probability = 0.1 (conservative assumption)

Gas detection and ESD failure probability = 0.05 (redundancy in gas detection and regular testing)

Ignition probability of accumulated gas = 0.1

Therefore explosion frequency = 5 x 10^{-7} p.a. and is very low.

Verification of the above simplified assessment can be carried out once the P&ID and enclosure dimensions are finalised.

9.5 DIESEL STORAGE FIRE RISK

The consequence calculation (see Section 7) showed that the heat radiation from a diesel fire does not extend beyond site boundary.

The potential for onsite incident escalation is low as there are no equipment and buildings within 15 kW/m^2 heat radiation distance from the tank.

9.6 CONCLUSIONS

The following conclusions were reached in the risk assessment.

4. The risk from the pipeline meets the land use planning risk criteria of HIPAP No. 4 for all land uses.
5. The explosion risks for gas compressor or turbine enclosure is of the order of 10^{-6} p.a. and very low, due to a number of safe guards built into the design.
6. The fire risk from diesel storage is very low and on a consequence basis alone there are no offsite effects and there would be no incident escalation on the site.

10 References

1 Hazardous Industry Planning and Advisory Paper No.6 (1992): Guidelines for Hazard Analysis, NSW Department of Urban Affairs and Planning, Sydney.

2 AS-2885 (1997): Pipelines - Gas and Liquid Petroleum (Known as the SAA Pipeline Code), Standards Association of Australia, Homebush, Sydney.

3 Hazardous Industry Planning and Advisory Paper No.4 (1992): Risk Criteria for Land Use Safety Planning, NSW Department of Urban Affairs and Planning, Sydney.

4 Venton and Associates Pty Ltd (2002): Macgen - Tomago Gas Supply Pipeline, Fracture Control Plan, Document No. 075-R01, Northbridge, NSW

5 TNO (2000): The RiskCurves Software - User Manual, Apeldoorn, The Netherlands.

6 Townsend, N.A & Fearnehough, G.D (1986): Control of Risks from UK Gas Transmission Pipelines, proceedings 7th symposium on line pipe research, American Gas Association, Oct.1986, Houston, USA.

7 Fearnehough, G.D. (1990), Pipeline Safety, Pipeline Technology Conference, Royal Flemish Society of Engineers, Oostende, Belgium, 1990.

8 Lees, F.P. (1996): Second Edition, Loss Prevention in the Process Industries, Butterworth Heinemann, UK.

9 Shell FRED version 4.0, Fire, Release , Explosion, Dispersion Hazard consequence modelling package, Shell Research Ltd.

10 Fearnehough, G.D. & Corder, I., Application of Risk Analysis Techniques to the Assessment of Pipeline Routeing & Design Criteria, International Conference on Pipeline Reliability, Calgary, Canada, 1992.

11 EGPIDG - European Gas Pipeline Incident Data Group (1992): Gas Pipeline Incidents, presented by F.J.Dawson - British Gas, at the International Gas Union Conference, Milan, Italy, June 1994.

12 CONCAWE (1993): Performance of Oil Industry Cross-Country Pipelines in Western Europe - Statistical Summary Of Reported Spillages, 1992.

13 European Gas Pipeline Incident Data Group (EGPIDG) (1988): Gas Pipeline Incidents, Pipes & Pipeline International, July-August 1988.

14 Cox, A.W., Lees, F.P. & Ang, M.L. (1992): *Classification of Hazardous Locations, IChemE*, Rugby, England.