Simmonds & Bristow
Established 1965 ACN 010 252 418 Pty Ltd

PRELIMINARY HAZARD ANALYSIS

QUEENSLAND CURTIS LNG (QCLNG) PROJECT - UPSTREAM AND PIPELINE COMPONENTS

Prepared for:

Queensland Gas Company C/- Environmental & Licensing Professionals

March 2009

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Preliminary Hazard Assessment
QCLNG Project - Upstream and Pipeline Components
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1. INTRODUCTION

Simmonds & Bristow was commissioned by Queensland Gas Company C/- Environmental & Licensing Professionals to prepare a Preliminary Hazard Assessment (PHA) of the upstream and pipeline components of the Queensland Curtis Liquefied Natural Gas (QCLNG) Project.

The QCLNG Project is being developed by an alliance between BG International Limited and Queensland Gas Company (BG-QGC). It involves the commercialisation of QGC's coal seam gas (CSG) resources in the Surat Basin (Central Queensland), processing to LNG in Gladstone (Central Queensland Coast) and export to overseas markets.

The requirement for a PHA was specified in the QCLNG Terms of Reference (TOR). Simmonds & Bristow was requested to address the land use safety component of the TOR, specifically related to hazardous events (e.g. fire or explosion) and the extent of impacts (e.g. heat radiation). It was a preliminary assessment based on the information provided by Queensland Gas Company that was available at the time of the study.

The transport and processing of CSG presents a risk because of the nature of the gas. The major constituent is methane, which is a flammable gas that can ignite in air on contact with a source of ignition.

The level of assessment was based on representative incident scenarios but not on a site-specific basis at this stage. The objective of this PHA was to determine the risks (e.g. types of incidents and hazard zones) associated with major project components such that site-specific analysis (e.g. impacts on specific receptors) may be conducted when detailed information is available. This will however enable risk prioritisation and planning for technological and site-based management controls (e.g. separation distances and emergency response).

This report has been prepared in accordance with Department of Urban Affairs and Planning (DUAP) (1992) *Guidelines for Hazard Analysis* Hazardous Industry Planning Advisory Paper No. 6 (and *Hazard Analysis Consultation Draft*, July 2008) and AS 4360:2004 *Risk Management*.

2. SCOPE OF WORK

The Scope of Work was to conduct a PHA of the upstream and pipeline aspects of the LNG Project. The PHA is a component of land use safety planning that evaluates the broader locational safety aspects of the proposed operation. This work covered the following requirements listed in the Draft Terms of Reference:

- Determine a set of representative incident scenarios associated with gas production, the operation of the field compression stations and central processing plants and gas gathering and export pipelines;
- Model the extent of thermal dispersion and hazard/ignition zones following hazardous incidents;
- Evaluate the likelihood of each scenario occurring; and
- Present risk contours for each scenario, where risks of fatality were significant.

The scope of work therefore included the quantitative analysis of unplanned CSG releases causing hazardous atmospheres (i.e. flammable), thermal dispersion in the event of ignition and potential for fatality and injury (e.g. heat effects from thermal radiation). Consequence modelling was conducted using a model developed in the United States called Areal Locations of Hazardous Atmospheres (ALOHA).

The scope of work did not include the components listed below.

- Detailed process analysis (e.g. HAZOP or Fault Tree analysis). This type of analysis would be conducted by a multidisciplinary team including plant designers, construction and process engineers, safety officers and operations management when the plant and pipeline design has been finalised.
- The marine operational activities of the QCLNG except to qualitatively assess the proposed sub-surface pipeline from the mainland to Curtis Island (off Gladstone).
- An analysis of scheduled releases, such as gas flaring, which is usually regulated by Environmental Licence conditions.

The primary references used in this report were:

- AS 4360. *Risk Management*;
- AS 2885.1. *Pipelines – Gas and liquid petroleum. Part 1: Design and construction*;
- Department of Urban Affairs and Planning (DUAP) (1992). *Guidelines for Hazard Analysis* Hazardous Industry Planning Advisory Paper No. 6;
- Department of Planning (2008). *Hazardous Industry Planning Advisory Paper No. 6. Hazard Analysis Consultation Draft.* Department of Planning NSW. July 2008;
- Department of Urban Affairs and Planning (DUAP) (1997). *Risk Criteria for Land Use Safety Planning*. Hazardous Industry Planning Advisory Paper No. 4; and
- SAA HB105. *Guideline to pipeline risk assessment in accordance with AS 2885.1*.

A list of documents provided by QGC for use in this report is attached as Appendix A.

3. HAZARD ASSESSMENT METHODOLOGY

3.1. Overview

The objective of the preliminary hazard analysis (PHA) was to evaluate risk levels and demonstrate that the design and operation can be carried out with an adequate level of safety. The assessment focuses on broader locational safety aspects. The follow approach to the hazard assessment was applied:

1. Review available information on design, layout and operating procedures;
2. Hazard identification;
3. Determination of hazardous incident scenarios;
4. Modelling and analysis of incident consequences;
5. Analysis of protection and prevention measures;
6. Analysis of the likelihood of initiating events and of outcomes;
7. Quantification of risk levels; and
8. Risk characterisation.

A conceptual overview of the hazard and risk assessment methodology applied is provided in Figure 1.

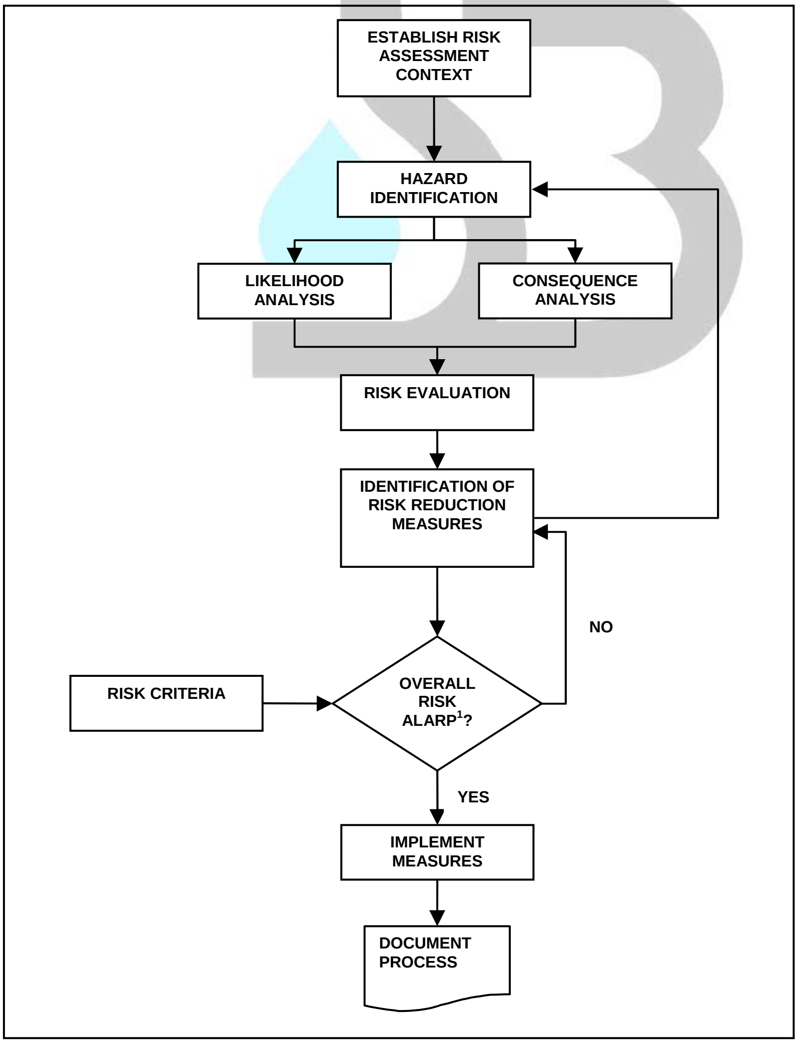


Figure 1: Hazard and Risk Assessment Methodology

3.2. Context Establishment

3.2.1. Background

BG and QGC have formed an alliance to commercialise QGC's coal seam gas resources in the Surat Basin. BG operates worldwide throughout the gas supply chain in exploration and production, power, transmission and distribution and LNG. QGC is an integrated energy company focusing on gas exploration, production and electricity generation. It has leases over 7,500 km^2 in the gas-rich Surat Basin of southern Queensland.

This Project was declared to be a 'significant project for which an EIS is required' by the Coordinator – General on the 4th July 2008. The declaration initiates the statutory environmental impact assessment (EIS) procedure of Part 4 of the *State Development Public Works Organisation Act* and subsequently the Terms of Reference (TOR) for the preparation of an EIS. Section 6 of the TOR describes the requirements for the Hazard and Risk Assessment, part of which is addressed in this report.

3.2.2. Project Stakeholders

The stakeholders of the QCLNG Project are:

- BG-QGC;
- Local landholders;
- Cultural heritage stakeholders;
- QGC employees;
- Tourists;
- Regional Shire Councils – Dalby, Banana Shire and Gladstone; and
- The Queensland State Government.

The internal stakeholders that provided information for use in this report include the following teams – Environment and Permitting, Pipeline Engineers, Production, GIS, Project Manager, Upstream Projects and Risk Coordinator.

3.2.3. Risk Management Context

The risk management process was applied to the upstream coal seam gas exploration, processing and pipeline activities. The assessment did not include the marine operational activities of the QCLNG. It did include potential outcomes of a release from the proposed sub-surface pipeline from the mainland to Curtis Island (off Gladstone) in the hazard identification phase.

The analysis covered the project activity during the operation of the upstream component of the project. The outcome of the hazard identification phase was the determination of a set of representative incident scenarios for consequence modelling. This preliminary assessment covered standard operating conditions and assumes that standard industry control measures are in place. More detailed risk analysis may include the use of fault trees or failure modes and effect analysis to assess the likelihood or probability of control measures failing.

The assessment predicted consequence zones (distance from source) for hazardous events. This information can be used to identify any potentially impacted receptors and evaluate cumulative and societal risks so that mitigation measures may be incorporated prior to the final development design (i.e. demonstrating an adequate level of safety). This assessment does not represent HAZOP analysis of the proposed operation (or its component parts).

3.2.4. Risk Criteria

Risk Contours

The TOR specified the following risk contours criteria for the analysis:

1. Fatality risk contours at 0.5, 5, 10 and 50 x 10^{-6} per year (see Table 1); and
2. Injury risk contours at 10 and 50 x 10^{-6} per year.

Table 1: Suggested Individual Fatality Risk Criteria for Various Land Uses

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 developments including retail centres, offices and entertainment centres	5
Sporting complexes and active open space	10
Industrial	50

Source: NSW Department of Planning 2008

Effects Analysis

The TOR specified the following risk effects criteria for the analysis:

1. Heat effects analysis using thermal radiation thresholds of 35kW/m^2 and 5kW/m^2.

The heat effects threshold of 35kW/m^2 has been adopted as the level at which a fatality occurs and the effects threshold of 5kW/m^2 has been adopted as the level at which an injury occurs. A more detailed list of heat radiation effects (DUAP 1997) is provided in Table 2.

Other potential consequences of a flammable gas release include explosion. The effects of explosion overpressure are presented in Table 3.

Table 2: Effects of Heat Radiation

Heat Radiation (kW/m²)	Effect
1.2	Received from the sun at noon in summer.
2.1	Minimum to cause pain after 1 minute.
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds exposure (at least second degree burns will occur).
12.6	• Significant chance of fatality for extended exposure. High chance of injury. • Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure. • Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure.
23	• Likely fatality for extended exposure and chance of fatality for instantaneous exposure. • Spontaneous ignition of wood after long exposure. • Unprotected steel will reach thermal stress temperatures which can cause failure. • Pressure vessel needs to be relieved or failure would occur.
35	• Cellulosic material will pilot ignite within one minute exposure. • Significant chance of fatality for people exposed instantaneously.

Source: Department of Planning NSW 2008

Table 3: Effects of Explosion Overpressure

Explosion Overpressure (kPa)	Effect
3.5 (0.5psi)	• 90% glass breakage. • No fatality and very low probability of injury.
7 (1.0psi)	• Damage to internal partitions and joinery but can be repaired. • Probability of injury is 10%. No fatality.
14 (2.0psi)	• House uninhabitable and badly cracked.
21 (3.0psi)	• Reinforced structures distort. • Storage tanks fail. • 20% chance of fatality to a person in a building.
35 (5.0psi)	• House uninhabitable. • Threshold of eardrum damage. • 50% chance of fatality for a person in a building and a 15% chance of fatality for a person in the open.
70 (10psi)	• Threshold of lung damage. • 100% chance of fatality for a person in a building or in the open. • Complete demolition of houses.

Source: DUAP 1997

The Levels of Concern used in the ALOHA model for potential flammable gas release scenarios (methane) are summarised in Table 4 and Table 5. The Levels of Concern for explosion overpressure and heat radiation were modified to ensure consistency with DUAP 1997 effect levels (the default ALOHA values are shown in brackets). The consequence analysis of heat effects was also run at 35kW/m^2 and 5kW/m^2 to provide a comparison with the criteria specified in the TOR.

Methane is classified as an asphyxiant in the guidelines on National Exposure Standards (NES) for atmospheric contaminants in the occupational environment (Australian Safety and Compensation Council 2009). Asphyxiants are gases that when present in an atmosphere in high concentrations, lead to a reduction of oxygen (see also Section 5.1). Therefore, there are no Australian guidelines on toxic concentrations of methane in air from an occupational health and safety perspective. In the absence of Australian guidelines, the default ALOHA values have been used as the Levels of Concern. The threshold level of most concern (TEEL-3) of 25000ppm (or 2.5%) equals 50% of the Lower Flammability Limit (LFL or LEL) (5.0%).

Table 4: Levels of Concern for Methane Release (not burning)

Hazard – methane not burning	Threat zone		
	Level of concern[1]		
	Classification	Units	Level
Toxic area from vapour cloud	TEEL-3	ppm	25000 (2.5%)
	TEEL-2	ppm	5000
	TEEL-1	ppm	3000
Flammable area of vapour cloud	60% LEL	ppm	26400
	10% LEL	ppm	4400
Blast area of vapour cloud explosion	Destruction of buildings	psi	10.0psi or 70kPa (8.0)
	Serious injury likely	psi	3.0psi or 21 kPa (3.5)
	Shatters glass	psi	0.5psi or 3.5 kPa (1.0)

TEEL = Temporary Emergency Exposure Limits (TEELs) defined by the US Department of Energy.

TEEL – 3 = Maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects.

TEEL – 2 = Maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

TEEL – 1 = Maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient health effects or perceiving a clearly defined objectionable odour.

LEL = Lower explosive limit = lower flammability limit. The minimum concentration of fuel in the air needed for a fire or explosion.

Blast area values in (brackets) are default values recommended by ALOHA.

Table 5: Risk Criteria for Methane Release (Burning)

Hazard – methane burning	Threat zone		
	Level of concern[1]		
	Classification	Units	Level
Thermal radiation	Potentially lethal within 60 seconds	kW/m^2	12.6[1] (10.0)
	2nd degree burns	kW/m^2	4.7 (5.0)
	Pain within 60 seconds	kW/m^2	2.1 (2.0)
Downwind toxic effects of fire by-products	No thresholds Not modelled by ALOHA		

[1] This guideline is more conservative than the Department of Planning (2008) criterion for fatality of 35kW/m^2

Separation Distances

The Department of Infrastructure, Planning and Natural Resources (DIPNR) document titled: *Locational Guidelines, Development in the Vicinity of Operating Coal Seam Methane Wells* provides advice to consent authorities in NSW on assessing proposals for development in the vicinity of existing and future operating CSG wells.

The guidelines describe the use of separation distances to provide a buffer between an existing and future operating CSG well (and associated equipment) and residential and sensitive uses (see Table 6). These separation distances reflect the level of technical and operational controls applied to CSG wells.

Separation distances to gas pipelines are also provided by Shire Planning Schemes. Schedule 2 of the Murilla Shire (includes the townships of Miles and Dalby) Planning Scheme Policy for example, recommends a minimum separation distance to petroleum and gas pipelines of 200m.

Table 6: Separation Distances between CSG Wellhead and Residential and Sensitive Uses in NSW (DIPNR 2004)

Well Configuration	Separation Distance (m)	
	Residential use[1]	**Sensitive use[2]**
Early intermediate Operation Wells (typically up to 2 years)		
Manual	10	20
Automatically controlled (With Separator/Optional Pump)	10	20
Automatically controlled (No Pump/Separator)	5	10
Established Wells (Typically after 2 years)		
Manual	10	15
Automatically Controlled (with Separator/Optional Pump)	10	15
Automatically Controlled (No Pump/Separator)	5	8

1 Residential and places of regular occupancy (e.g. where people are present on a regular basis).

2 Sensitive use = schools, hospitals, aged persons accommodation and other uses where vulnerable people are concentrated.

3.3. Hazard Identification

The objective of this phase of the analysis was to identify the hazards and possible initiating events for each major component of the project and the possible consequences (to people, property or the environment) as a result of these events, in a broad locational sense. The hazard identification process was conducted in accordance with NSW Department of Planning (2008). The approach was to review available process information to develop a Word Diagram. The process information reviewed included:

- QCLNG Project Upstream and Pipeline Base Case Development Plan;
- Internal risk assessment documents;
- HAZOP studies of similar developments;
- Compressor drawings; and
- Lot Plans.

For the purposes of this PHA, the most significant initiating event was considered to be the loss of containment of coal seam gas (CSG), which is a flammable gas. The approach therefore was to evaluate the major components of the project (based on available information) and identify the potential for loss of containment. The major components evaluated were:

- Well head and gas/water separator;
- Pipelines (e.g. HDPE flowlines, steel trunklines and UIC_Export pipeline);
- Screw compressors at Field Compression Stations (FCS); and
- Reciprocating compressors at Central Processing Plants (CPP).

The loss of containment of gas is usually the result of equipment failure. The common reasons for leaks or unplanned releases are:

- Failure of pressure piping and joints through erosion, corrosion, pressure surge or mechanical impact;
- Failure of valves through the valve itself or an increase in line pressure above the set pressure;
- Failure of pumps though seal failure, corrosion or erosion in pump casing of failure of the pump shaft; or
- Pressure increases or surges.

The other scenarios considered were incidents associated with the storage of diesel fuel or storage and use of triethylene glycol (TEG) used in the dehydrators units in the Central Processing Plants (CPPs).

3.4. Risk Analysis

3.4.1. Consequence Analysis

The major consequences of a coal seam gas release (considered to be 100% methane for the purposes of this PHA) for release and/or ignition are described in Figure 2. These are the types of scenarios that would result in thermal dispersion and hazard ignition zones as specified in the TOR (note: a loss of containment of pressurised gas may also result in an instantaneous temperature drop from expansion). The potential consequences of a diesel or triethylene glycol spill also include downwind toxic effects or a pool fire (and subsequently thermal radiation).

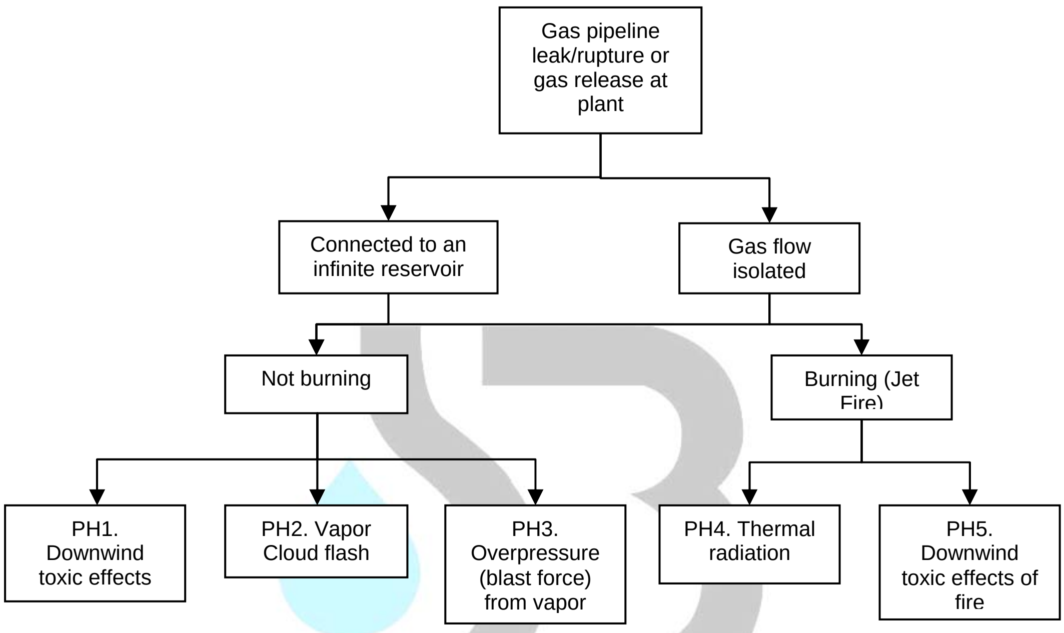


Figure 2: Consequence Analysis

The consequences of a hazardous event can be analysed qualitatively or quantitatively. An example of a qualitative assessment presented by Comcare (Australia) is provided in Table 7 (for Major Hazard Facilities). Other examples of qualitative consequence matrices are provided in AS 4360 *Risk Management.*

Table 7: Examples of Qualitative Descriptors (Comcare 2008)

Consequence descriptor	Insignificant	Minor	Moderate	Major	Catastrophic
Health and safety values	A near miss, first aid injury	One or more lost time injuries	One or more significant lost time injuries	One or more fatalities	Significant number of fatalities
Environmental values	No impact	No or low impact	Medium impact Release within facility boundary	Medium impact outside the facility boundary	Major impact event
Financial loss exposures	Loss below $5000	Loss $5000 to $50000	Loss from $50000 to $1M	Loss from $1M to $10M	Loss above $10M

Source: Comcare (2008). *Major Hazard Facilities. Hazard Identification*

The consequence analysis was conducted using the ALOHA (Areal Locations of Hazardous Atmospheres) Model. This model provides quantitative estimates of threat zones, i.e. the distance to a pre-defined level of concern for toxic effects (airborne concentration, ppm), vapour cloud flash (based on flammable limits of the gas, %) and thermal radiation (kW/m^2).

ALOHA 5.4 is a computer-based accident release model that is used worldwide for response, planning, training and academic purposes. ALOHA uses information provided by its operator and physical property data from its chemical library to predict the source strength and dispersion of an accidental chemical release. ALOHA was developed jointly by the United States Environmental Protection Agency (USEPA) and the Emergency Response Division of the National Oceanic and Atmospheric Administration (NOAA).

3.4.2. Likelihood Analysis

Likelihood Data

The likelihood of hazardous events identified in this report was assessed by reviewing data on equipment failure and ignition probabilities. The types of equipment items that can fail (of relevance to this report) included pipelines, valves and instrument fittings. The sources of information reviewed were:

- Australian Standards (e.g. SAA HB105/AS 2885);
- Federal and State Government Publications;
- Literature on failure rates in process industries (e.g. Lees 1992);
- Industry publications (e.g. Australian Pipeline Industry Association (APIA) and Pipeline Operators Group); and
- Case studies on similar developments (e.g. Environmental Impact Assessments).

Most of the data is likelihood data, which is an expression of the chance of something occurring in the future. For example, it might be estimated that the likelihood of catastrophic vessel failure is one chance in a million per year (or 1×10^{-6} per year). Examples of equipment failure and fire likelihood data are presented in Table 8. Information on pipeline failure rates is provided in Table 9 and Table 10 (the frequency (or likelihood) determination for pipeline threats specified by AS 2885.1/SAA HB105).

The Health and Safety Executive (2002) reports the frequency of valve leaks to be 170×10^{-6} per valve per year. Cox, Lees and Ang (1992) report a failure rate of 100×10^{-6} per instrument fitting per year. This information was used in the assessment of releases from compressor stations.

Table 8: Equipment Failure and Fire Probability

Item	Likelihood of failure (in one million per year per item)	Likelihood of fire (in one million per year per item)
Storage Vessel	600	1000
Bund	0.1	10
Road Tanker	10	2
Pipeline	6-12	0.20-0.50
Pumps		
• seal	5000	50
• shaft	200	4
• casing	20	1

Source: Department of Environment and Planning, Sydney (1985)

Table 9: General Failure Rate Data for Gas Pipelines

Cause	Failure Rate (per km-year)	Failure Rate (per 1000 km-yr)
External force	3.00×10^{-4}	0.3
Corrosion	1.00×10^{-4}	0.1
Material defect	1.00×10^{-4}	0.1
Other	5.00×10^{-5}	0.05
Total	**5.5×10^{-4}**	**0.55**

Source: R2A (2002)

Table 10: Frequency Determination for Pipeline Threats

Frequency of occurrence	Description	Nearest numerical frequency for guidance (per 1000km per year)
Frequent	Expected to occur at least once per year	1 or greater
Occasional	Expected to occur several times in the life of the pipeline	0.1
Unlikely	Not likely to occur in the life of the pipeline, but is possible	0.01
Remote	Very unlikely to occur in the life of the pipeline	0.001
Improbable	Examples of this event have occurred historically, but it is not anticipated for the pipeline at this location	10^{-5}
Hypothetical	Theoretically possible but has not occurred at this date	10^{-6} or lower

Source: SAA HB105

Probability Data

Some data is presented as a probability, which is a dimensionless expression of the chance of something occurring. Examples of ignition probability data for gas releases of varying release rates is presented in Table 11. .

Table 11: Probability of Ignition following CSG Release

Release Rate (kg/mins)	Ignition Probability (Gas or Mixture)	
	Probability	Likelihood (1×10^{-6})
<60	0.01	10 000
60 – 3000	0.07	70 000
>3000	0.3	300 000

Source: Cox, Lees and Ang (1992)

Incident Data

The Pipeline Operators' Group/Australian Pipeline Industry Association (POG/APIA) pipeline incident database provides information on average incident rates (Kimber 2005). Incidents reported comprise coating damage, steel damage, leaks and ruptures. A distinction is made in AS 2885 between pipeline failure (e.g. corrosion and material defects) and external interference and/or third party damage (e.g. damage from excavator machinery).

The following information and incident data (~1985 – 2005) was reported by Kimber 2005 in *Australian Pipeline Research Program Keynote Address – Keeping the Australian Pipeline Standards up to Date.*

- The most common cause of pipeline damage is external interference.
- External interference accounts for 76% of all incidents.
- The second most common cause of pipeline damage is corrosion.
- There have been no deaths or injuries reported (i.e. ~1985 -2005).
- There were 6 ruptures and 20 leaks reported to the incident database.
- Pipe deformation (scratches, gouges and dents) accounts for two thirds of incidents.
- The overall accident rate is 0.13 per 1000 km-yr.
- The average incident rate for loss of containment is 0.015 per 1000 km-yr.
- The average incident rate for loss of containment is an order of magnitude lower than the loss of containment rates in Europe and the USA.
- The incident rate for external interference varies with location class, ranging from 0.05 per 1000 km-yr in remote rural areas to 0.48 per 1000 km-yr in rural residential and suburban areas.

External interference, which is sometimes referred to as "third party" interference means that someone other than the operator has damaged the pipeline. Damage is typically caused by excavating equipment used to maintain or construct adjacent services (e.g. fencing).

Corrosion of a pipeline can be either internal or external. The corrosion of a pipe wall or weld usually results in a very small hole (pinhole). Corrosion may start from an existing weak point on the pipe or weld or be caused by an electrochemical difference between the soil and pipeline surface.

Mechanical failures are essentially failures of the pipeline wall or welds. These may, for example, occur when a pipeline is operated continuously at a pressure considerably higher than the design specification, leading to metal fatigue, or as a result of a weld failure because of a piece of slag causing weakness in the joint. Natural hazards, such as floods, landslides, earthquakes and sinkholes may also cause damage to pipelines.

4. CSG PRODUCTION, PROCESSING AND PIPELINES

4.1. General Layout

The general layout of the upstream components of the QCLNG project is shown in Figure 3. The coal seam gas (CSG) is produced at the well and processed (i.e. compression and dehydration) in two stages prior to export:

1. Field Compression Station (FCS); and
2. Central Processing Plant (CPP).

Each FCS processes gas from fifty (50) wells. Each CPP processes gas from three (3) FCS.

The CSG well typically comprises a well head collar, a pump, a gas/water separator and a power source (if pump used at well head). The gathering system from the CSG wells to the FCS comprises HDPE flow lines (Internal Diameter, ID = 14.3cm) of approximately 2km in length. The flow line inlet pressure is approximately 300kPa. Wells may be manually or automatically controlled.

CGS is compressed to a pressure of approximately 1500kPa at the FCS, which comprises eight (8) screw compressors. CSG is transported to the CPP by Class 150 steel pipeline (ID = 39.7cm). The maximum distance between the FCS and CPP was estimated to be 785km.

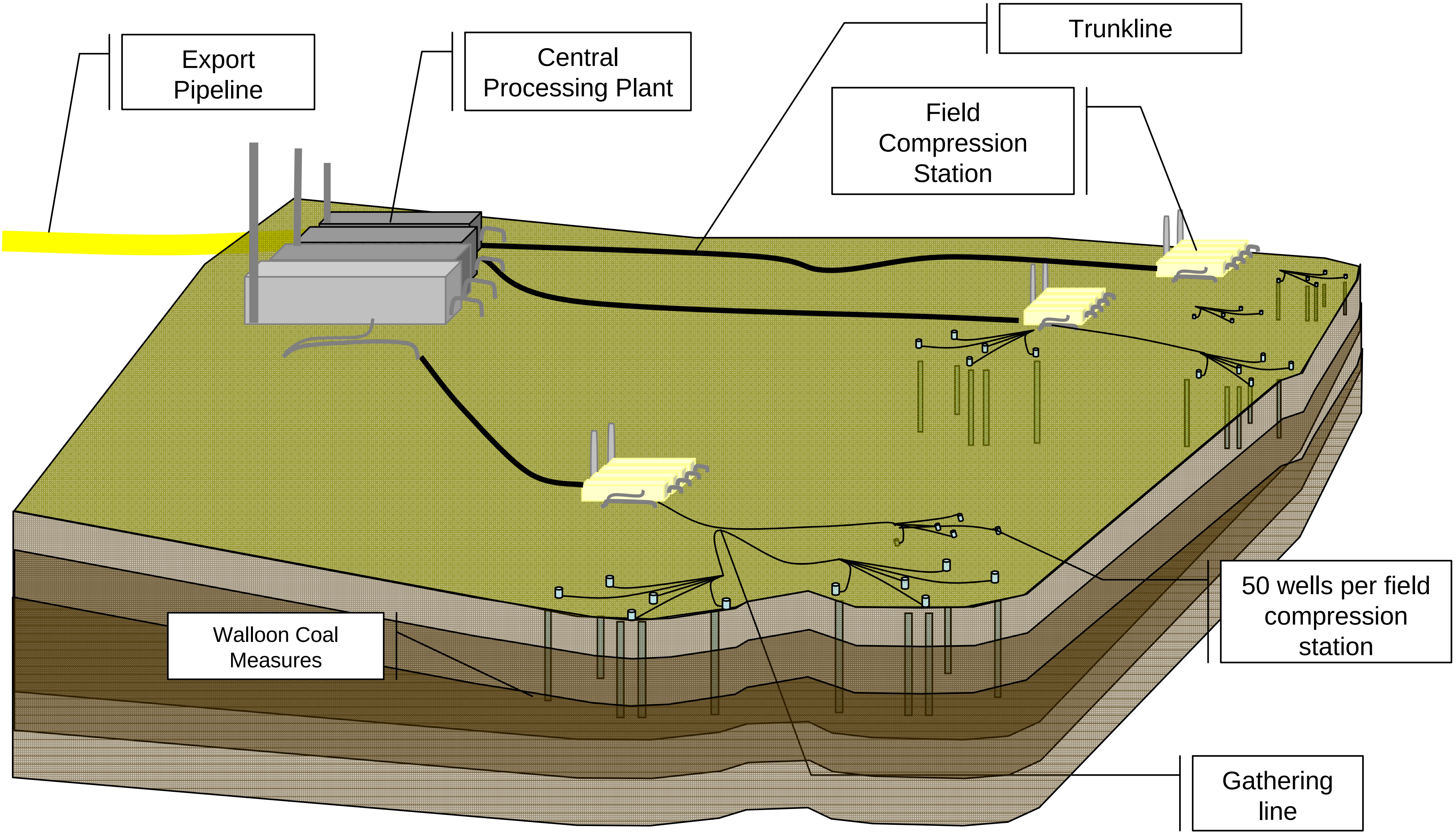
The CPP further compresses the gas to 10200kPa. Each CPP contains ten (10) reciprocating compressors. Water vapors are removed from the gas stream using triethylene glycol (TEG) towers. The compressed gas from the CPP flows via the Upstream Infrastructure Corridor (UIC), including the gas collection header, to the gas export pipeline.

The function of the UIC is to connect all QGCs production leases for inlet to the export line in the Miles area. The gas export pipeline extends from the production leases in south central Queensland to the proposed LNG facility in Gladstone. The UIC and export pipelines are Class 600 steel with an ID = 103.4cm (1.03m).

The total length of the UIC and gas collection header is estimated to be 203km while the total length of the export pipeline is estimated to be 380km.

Figure 3: Layout of a Gas Production and Processing Node

Gas Processing



4.2. Gas Production and Processing

The primary design specifications of the gas production and processing stages of the project, relevant to this PHA, are summarised in Table 12, Table 13 and Table 14. These tables provide assumptions for modelling purposes based on preliminary design objectives.

More specific modelling of the gathering system was conducted by Queensland Gas Company (*pers comm*. March 2009) to determine gas pressures at the wellhead and this information is summarised for two areas of the CSG field below. These calculations support the assumptions used in consequence modelling.

- Case 1a – The flow rate ranges from ~20 – 33mmscfd (million standard cubic feet per day of gas) near the suction header at pressures of ~30 – 41psi (206 - 283kPa);
- Case 1b – HDPE flow lines carry ~17mmscfd at a pressure of ~47psi (324kPa); and
- Case 2 – the flow rate ranges from ~62 – 82mmscfd near the suction header at a pressure of ~36psi (248kPa).

Table 12: Gas Well Parameters

Component description	Function	Pipeline type	MAOP	Shut-in Pressure	Pressure	Diameter	Wall thickness	Internal diameter	Pipeline length	Individual lengths	Gas supply control	Max length from reservoir or isolation valve
			MPa	**kPa**	**kPa**	**mm**	**mm**	**cm**	**m**	**m**	**type**	**m**
Wellhead	Gas supply node	na	0.7	3790 (new well) (note 1)	(350 – 700) Modelled data - 206 to 324kPa	110	no data	no data	na	na	Finite – pump (see also note 2)	400 (assumed depth of well)
		na	na	1038 kPa (after two years) (note 1)	na	110	no data	no data	na	na	Finite – pump (see also note 2)	400

na = not applicable

Notes

1 DIPNR 2004

2 A free flowing well (rather than a well and pump) would represent an infinite source. However, an infinite source was assumed for a full bore rupture.

Table 13: Compressor Parameters

Pipeline description	Function	Pipeline type	Pipeline inlet pressure	Diameter	Wall thickness	Internal diameter	Gas supply control	Max length from reservoir or isolation valve
			kPa	mm	mm	cm	type	m
Compressor discharge pipeline	Transport compressed gas	Steel	1500 (screw compressor) 10200 (reciprocating compressor)	109	9	10	Finite – isolation valve before compressor	Not available

Table 14: Pipeline Parameters

Pipeline description	Function	Pipeline type	MAOP	Pipeline inlet pressure	Diameter	Wall thickness	Internal diameter	Pipeline length	Individual lengths	Gas supply control	Max length from reservoir or isolation valve
			MPa	kPa	mm	mm	cm	m	m	type	m
Flow lines	HDPE flow lines from well head to FCS	HDPE	Gas – 1.25MPa	300 (note 1a)	152	9	14.3	2000	20m	Finite - non return value after gas/water separator	2000
Trunklines	FCS to CPP	Steel, Class 150	1.86 MPa (1856 kPag)	1500 (note 1b)	406	9	39.7	5000	na	Finite - isolation valve	5000
Upstream infrastructure corridor (UIC) containing Gas Collection Header	Connection of all QGC's production leases (note 2) for inlet to the export line in the Miles area	Steel, Class 600	10.2	10200 (note 1c)	1050	15.66	103.4	203000	18	Finite - isolation valve	30000 (note 3) Model input = 10000 max
Gas export pipeline	Pipeline from QGC's production leases in south central Queensland to the LNG facility in Gladstone	Steel, Class 600	10.2	10200 (note 1d)	1050	15.66	103.434	380000 (note 4)	18	Finite - isolation valve	30000 (note 3) Model input = 10000 max

na = not applicable

Notes

1a	Field pressure = 200-300kPa.
1b	Trunkline pressure = ~1500kPa
1c	Inlet pipeline pressure to gas header export = 10000kPa
1d	Inlet pressure to gas export pipeline = 9600kPa
2	Lateral pipelines may also connect additional CSG fields to the transmission pipeline
3	Maximum spacing of valves in semi-rural areas = 30km (AS 2885), in urban areas = 15km. Maximum input to model is 10km
4	Sub-sea portion = ~3km

5. HAZARD IDENTIFICATION

5.1. Coal Seam Gas Composition

Queensland Gas Company provided information on the coal seam gas composition. This information is provided in Table 15. CSG is comprised primarily of methane. The methane content increases slightly (from 97.51% to 97.8%) after processing. Consequence modelling of hazardous events identified in this report assumes the gas release is 100% methane.

Table 15: Composition of Coal Seam Gas

Process Stage	Compound	Mol %
Field composition[1]	Methane	97.51
	Nitrogen	2.23
	Ethane	0.01
	Carbon dioxide	0.22
Processing plant discharge line (P01)[2]	Methane	97.8
	Nitrogen	2.0
	Ethane	0.02
	Carbon dioxide	0.16

[1] At the well head, pre-compression and processing
[2] This gas is representative of what will be sent to the LNG Plant

Methane is a flammable gas, which means that it can ignite in air on contact with a source of ignition. The lower flammability limit (LFL or LEL) is 5% and the upper flammability limit is 15%.

Methane is also an asphyxiant. This means that high concentrations of methane in the atmosphere lead to a reduction of oxygen concentration by displacement or dilution. Atmospheres deficient in oxygen do not provide adequate sensory warning of danger and most simple asphyxiants (such as methane) are odourless. Unconsciousness and death can rapidly ensure in an environment that is deficient in oxygen. Many of the asphyxiants (such as methane) also present an explosion hazard.

5.2. Process Chemicals

Triethylene glycol is used for gas dehydration in the Central Processing Plant (CPP) because it is hygroscopic. Triethylene glycol (TEG) is a liquid higher glycol of very low vapor pressure with uses that are primarily industrial. It has a very low order of acute toxicity by inhalation (the potential for vapor and aerosol generation is low). It does not produce primary skin irritation. Acute eye contact with the liquid causes mild local transient irritation but does not induce corneal injury. Animal maximisation and human volunteer repeated insult patch tests studies have shown that TEG does not cause skin sensitisation (HSDB 2009).

TEG is not classified as Dangerous Goods according to the Australian Code for the Transport of Dangerous Goods by Road and Rail. It has a flash point of 168°C and therefore is classified as a combustible liquid.

Combustible liquids are liquids that burn, but are more difficult to ignite than flammable liquids. They have a flashpoint greater than 60.5°C and are not classified as dangerous goods (whereas liquids with a lower flashpoint are dangerous goods Class 3 – flammable liquids). C1 combustible liquids have flash points of <150°C while C2 combustible liquids have flash points >150°C. TEG therefore is classified as a C2 combustible liquid.

Each TEG unit will hold approximately 5000L. In addition, approximately 10 drums (or 2000L will be stored at the warehouse. TEG should be stored in accordance with AS 1940:2004. *The Storage and Handling for Flammable and Combustible Liquids*.

5.3. Fuels

Diesel fuel is a C1 combustible liquid. It is more difficult to ignite than flammable liquids such as petrol. Diesel is not classified as a dangerous good because of this property. Diesel exhausts (e.g. fine particulates and combustion gases) may cause health effects in confined areas with poor ventilation.

Diesel will be stored at the Central Processing Plants (CPPs) in either 5000L or 10000L tanks. Back up diesel generators will be stored at the Field Compression Station (FCS) but storage quantities are very low. Diesel should be stored in accordance with AS 1940:2004. *The Storage and Handling for Flammable and Combustible Liquids*.

5.4. Hazardous Scenarios

The hazardous scenarios addressed in this PHA are those resulting from an unplanned loss of containment of coal seam gas (CSG). These scenarios do not include gas flaring, which is considered to be part of the process design. However information was provided by Queensland Gas Company on gas flaring in a CPP (based on production of 70 TJ/day) and is summarised below:

- Total emergency shut-downs (ESDs) = 3.5 times per year for a duration of 0.5-1.0hrs per shutdown;
- Compressor shut down or stops that will create a minor flare = 570/year;
- Compressor stops for nomination, compressor failure or service; and
- Duration is the volume and time it takes for blow down.

The potential hazardous scenarios identified for consequence modelling purposes across gas production, processing, gathering and export are summarised in Table 16 to Table 19. Additional information on potential incident scenarios is provided in Appendix B - HAZOP analysis for the Kenya Field Compression Station Upgrade.

Table 16: Hazard Identification Word Diagram – CSG Wells

Operational area	Possible initiating events	Possible consequences	Prevention and protection measures
Whole area	Ignition source within hazardous zone	Fire or explosion	Shut down valve to isolate the well
			Exclusion zone and control of potential ignition sources
			Gas or fire detection system for automatically controlled wells
			All electrical equipment is appropriate to the hazardous area classification
			Protection of wells from impact
			Permit to work procedures including Job Safety Analysis for each work over
			Safety Management System
Wellhead	Valve failure and gas release/major leak	Fire or explosion	Well head collar has a pressure rating of at least twice the maximum shut-in pressure
			Non-return valve installed to prevent backflow from the flow line in the event of a major leak
	Overpressurisation of the gathering system (flow lines)	Leak or rupture	Choke valve to limit maximum flow from the well
			Pressure piping upstream of the choke designed to withstand very high pressure
Gas/water separator	Valve failure and gas release	Fire or explosion	Separator has a design pressure rating of at least equal to the maximum operating pressure of the gathering system
			Pressure Safety Valve (PSV) sufficient to relieve full flow from the well with vertical vent line
Flare	Flame-out	Vapour cloud - toxic fumes, fire or explosion	Exclusion zone and control of potential ignition sources
Electric or hydraulic power skid	Failure of pumping rods	Gas pressure increase at wellhead	Automatic pump shut down device
	Diesel tank failure and spill	Pool fire	Emergency shut down procedures
	Release high pressure fluids (hydraulic system)	Direct injury or death	Bunded area
		Failure of pumping rods	Bunded area
			Emergency shut down procedures

Table 17: Hazard Identification Word Diagram – Field Compression Station

Operational area	Possible initiating events	Possible consequences	Prevention and protection measures
Whole station	Fire or explosion	Human injury	Secure site
		Facility damage	Control of ignition sources
			ESD pushbutton at station gate
			Evacuation alarm
Compression (8 screw compressors)	Loss of one or more compressors	Gas release and vapour cloud	Automatic isolated valves on suction and discharge
			Gas detection system to initiate alarms, shutdowns or deluge systems
	Loss of containment from station pipework and equipment[3]	Fire or explosion	Automatic blowdown, gas detection system
	Failure of temperature and pressure control		Flare - cold vent
			ESD procedures – isolation of the cause of the problem and set all systems into a safe condition
	Temperature drop due to expansion of pressurised gas	Damage to equipment pipework nearby	Plant layout
		Human injury – low temperature burns	ESD procedures – isolation of the cause of the problem and set all systems into a safe condition
	Fire or ESD	Downwind effects of fire by-products	ESD procedures
			Venting at wellhead
Compressor blowdown[1]	Shut-down and unload	Vapour cloud	Plant layout
	ESD	Fire or explosion	Cold vent stack
			Venting at wellhead
Cold vent stack screw stations[2]	Intended release - straight to atmosphere	Vapour cloud	Plant layout
		Fire or explosion	Venting at wellhead
			Duration of operational flare events controlled by licence conditions
			ESD
Power generation (gas with diesel back-up)	Diesel release	Pool fire	Bunding
			Plant layout
	Vapour emissions	Vapour cloud	Plant layout
Waste oil storage (Oily Water Tank)	Spill	Contaminated land	Bunding
		Contaminated waterways	

Operational area	Possible initiating events	Possible consequences	Prevention and protection measures
	Fire	Downwind effects of fire by-products	Vent with a flame arrester
			Electrical hazardous area classification takes venting into account

[1] Designed protection measure
[2] Designed protection measure to limit plant inlet pressure in case of loss of one or more compressors without the need to vent at the wellhead. PSVs and blowdowns go straight to atmosphere in-situ
[3] Loss of containment due to corrosion, mechanical damage, flange, gasket and fitting leaks

Table 18: Hazard Identification Word Diagram – Central Processing Plant

Operational area	Possible initiating events	Possible consequences	Prevention and protection measures
Whole plant	Fire or explosion	Human injury	Secure site and control of ignition sources
		Damage to facility	ESD and pushbuttons[6]
			Evacuation alarm
Reciprocating compressor package (10 reciprocating compressors)	Loss of one or more compressors	High temperature, high pressure gas release[5]	Automatic isolated valve on suction, discharge and automatic blowdown
			Gas detection system to initiate alarms, shutdowns or deluge systems
	Loss of containment from station pipework and equipment[4]	Vapour cloud	Automatic blowdown, gas detection system
	Failure of temperature and pressure control	Fire or explosion	ESD procedures – isolation of the cause of the problem and set all systems into a safe condition
		Damage to facility	
	Fire	Toxic by-products	Isolate and stop as per ESD[6]
		Human injury	Blow down plant to flare
		Damage to facility	Gas detection or Infrared fire detection
	Temperature drop due to expansion of pressurised gas	Damage to equipment pipework nearby	Plant layout
		Human injury – low temperature burns	ESD procedures – isolation of the cause of the problem and set all systems into a safe condition
TEG gas dehydration[1]	TEG spill (hot and cold)	Human injury	Bunding
		Release to environment	Spill containment measures
	Fire	Toxic by-products	Isolate and stop as per ESD[6]
		Human injury	Blow down plant to flare
		Damage to facility	Infrared fire detection
TEG regeneration[2]	TEG spill	Human injury	Bunding
	Steam release	Release to environment	Site layout
			Spill containment measures
Flare[3]	Flame-out	Vapour cloud - toxic fumes, fire or explosion	Flare design (seal, dual pilots, automatic re-ignition)
			ESD[6]
Power generation (gas with diesel back-up)	Diesel release	Pool fire	Bunding
			Plant layout

Notes

1 Dehydrator units to remove water vapours from gas stream. TEG is used in an absorber tower to absorb the water vapours from the gas.

2 Wet glycol is heated (e.g. >150°C) to regenerate the glycol

3 Flare to which blowdowns and compressor start gas are directed

4 Loss of containment due to corrosion, mechanical damage, flange, gasket and fitting leaks

5 Assumptions - temperature = 100°C and pressure = 10000kPa

6 Isolate the plant and stop all compressors and TEG units

Table 19: Hazard Identification Word Diagram – Pipelines

Operational area	Possible initiating events	Possible consequences	Prevention and protection measures
All pipelines	Poor quality control in pipe fabrication and laying Mechanical failure of pipeline wall or welds	CSG leak	Design in accordance with AS 2885.1. Quality control in pipe fabrication. Quality control in pipe laying operations.
	Damage where pipeline crosses obstacles	CSG leak	
	Deviation from normal operating conditions (temperature or pressure) leading to fatigue	CSG leak	
	Thermal stress (e.g. fire)	CSG release and added fuel	
HDPE flow lines	External interference e.g. damage from excavator machinery	CSG release and ignition causing fire or explosion	Physical and procedural measures in accordance with As 2885.1 (see measures for steel pipelines).
	Earth movement or soil subsidence	CSG leak	Design measures in accordance with AS 2885.1, including control of fracture.
Steel trunklines, UIC and export pipeline	External interference	CSG release and ignition causing fire or explosion CSG release and sudden temperature drop	R1/R2 location classification requires one physical and two procedural measures. Adequate depth of cover important.
			Physical measures (in accordance with AS 2885.1): • Cross country sections – minimum depth – 750mm. • Beneath roads – 1200mm unless rock. • Fire break – 1200mm. Physical protection of the pipe in any exposed location.
			Procedural measures: • Marking by signs and patrolling. • In accordance with AS 2885.1 – warning signs required at each change of direction and crossing and must be line of sight.
			Installation of protective devices such as emergency isolation valves and non-return valves. Leak detection by automatic sensing devices.
	Earth movement or soil subsidence	CSG leak	Design measures in accordance with AS 2885.1, including control of fracture.
	Corrosion (internal or external)	CSG leak	Protective coatings to inhibit corrosion.

Operational area	Possible initiating events	Possible consequences	Prevention and protection measures
	Electrochemical differences between the soil and pipeline surface Existing weak point on the pipe or weld		
Marine pipelines	Damage where pipeline crosses obstacles Deviation from normal operating conditions (temperature or pressure) leading to fatigue Bending, external loading or environmental forces must be addressed	CSG leak to marine environment Possible ignition following discharge to the atmosphere. Risks are highest in circumstances where methane accumulates in an enclosed space. Release rate from the water surface expected to be lower than from the pipeline. Environmental impacts expected to be low apart from addition of nutrients.	AS 2885 Marine pipelines should be designed to withstand the anticipated pressure and pressure surges Factors to be considered include: • Internal pressure capabilities; • Collapse resistance of pipe; and • Weighting

6. RISK ANALYSIS

6.1. Likelihood Analysis

For this preliminary assessment, the likelihood analysis has two components relating to a CSG release, ignition and jet fire:

1. The likelihood of loss of containment; and
2. The likelihood of ignition.

The incident rates described by the Australian Pipeline Research Program (2005) were lower than those reported by other sources (see Table 8 and Table 9) but generally consistent with the frequency classifications provided by AS 2885 and the SAA HB105. A comparison is provided below:

- The loss of containment rate of 0.015 per 1000 km-yr (POG/APIA);
- The overall accident rate of 0.13 per 1000 km-yr (POG/APIA); and
- Reported failure rate of 0.55 per 1000 km-yr (R2A).

The higher failure rate presents a worst case scenario while the lower rates, reported by the Pipeline Operators Group (POG)/Australian Pipeline Industry Association (APIA) are representative of the (reported) failure rates in Australia, particularly rural Australia.

There was no available information on failure or release rates from gas wells or compressors specifically, but there was for flanges, valves and instrument fittings. Information provided by the Client from past experience indicates a low likelihood of significant releases during operation at the wellhead although minor leaks have been caused during installation. The only other release event noted at a wellhead was caused by an increase in pressure in the gas/water separator above the set pressure, which resulted in gas being bypassed to the flare line.

As for the pipeline scenarios, more detailed assessment would consider the number of flanges, valves and instrument fittings to enable use of failure data on a *per part* basis and estimate of risks from the station as a whole. More detailed analysis would also consider the risks associated with the failure of more than one component (e.g. compressor) at any one time although this scenario is considered unlikely given Emergency Shut Down procedures.

Therefore, generic data for pipelines, valves and instrument fittings have been used in this assessment. A summary of incident rates, ignition probabilities and total estimate of likelihood of a fire are provided in Table 20 and Table 21. This analysis shows the most likely event leading to fire is a release in the FCS or CPP.

Table 20: Summary of Likelihood Data for CSG Release and Ignition – Well and Compressor Scenarios

Release Source	Hole size	No. parts	Pressure	Likelihood of release	Likelihood of release	Calculated release rate	Ignition Probability[2]	Likelihood of fire (note 1)
	mm		(kPa)	(x 10-6 per part per year)	(x 10-6 per year)	(kg/mins)		(x10-6 per year)
Gas well (full bore)	110	1 well	300	20 (note 4)	20	54	0.01	0.200
	10	1 well	300	20 (note 4)	20	1.6	0.01	0.200
Screw compressor/FCS	25	8 x 4 (note 2)	1500	170 (note 5)	5440	21	0.01	54
Reciprocating compressor/CPP	25	10 x 4 (note 3)	10200	170 (note 5)	6800	21	0.01	68

1 Derived from consequence modelling described in the following section
2 See Table 11

Notes:

1 Likelihood of fire = likelihood of release x likelihood of ignition

2 No. compressors per FCS, assumes 4 valves

3 No. compressors per CPP, assumes 4 valves

4 Failure probability for a casing pump

5 Assuming 4 valves per compressor on inlet and discharge lines - 25mm hole size

Table 21: Summary of Likelihood Data for CSG Release and Ignition – Pipeline Scenarios

Release Source	Hole size	1000 km	Pressure	Likelihood of release	Likelihood of release	Calculated release rate	Ignition Probability[2]	Likelihood of fire (note 1)	Likelihood of fire (note 1)
	mm	Units project	(kPa)	(per 1000km per year)	(per 1000km per year project)	(kg/mins)		(per 1000 km per year project)	(per million km per year project)
Loss of containment rate (POG/APIA 2005)									
HDPE flow lines (full bore) (note 6)	143	3	300	0.015	0.045	43	0.01	0.0005	0.45
Steel trunklines (note 7)	25	0.15	1500	0.015	0.00225	67	0.07	0.0002	0.16
UIC_Export	25	0.583	10200	0.015	0.008745	504	0.07	0.001	0.61
	150	0.583	10200	0.015	0.008745	16600	0.3	0.003	2.62
Incident rate (POG/APIA 2005)									
HDPE flow lines (full bore) (note 6)	143	3	300	0.13	0.39	43	0.01	0.004	3.90
Steel trunklines	25	0.15	1500	0.13	0.0195	67	0.07	0.001	1.37
UIC_Export	25	0.583	10200	0.13	0.07579	504	0.07	0.005	5.31
	150	0.583	10200	0.13	0.07579	16600	0.3	0.023	23
General failure rate (R2A 2002)									
HDPE flow lines (full bore)	143	3	300	0.55	1.65	43	0.01	0.017	17
Steel trunklines	25	0.15	1500	0.55	0.0825	67	0.07	0.006	5.78
UIC_Export	25	0.583	10200	0.55	0.32065	504	0.07	0.022	22
	150	0.583	10200	0.55	0.32065	16600	0.3	0.096	96

1 Derived from consequence modelling described in the following section

2 See Table 11

Notes:

1 Likelihood of fire = likelihood of release x likelihood of ignition

2 No. compressors per FCS, assumes 4 valves

3 No. compressors per CPP, assumes 4 valves

4 Failure probability for a casing pump

5 Assuming 4 valves per compressor on inlet and discharge lines - 25mm hole size

6 Total length of HDPE flow lines estimated to be 50 wells x 2km x 3 FCS x 10 CPP

7 Total length of steel trunklines estimated to be 3 FCS x 5km x 10 CPP

6.2. Consequence Analysis

The consequences of gas releases from the following stages of the development were modelled:

1. Gas wellhead;
2. Screw compressor;
3. Reciprocating compressor;
4. HDPE flow lines; and
5. Steel pipelines.

The model inputs were based on the data provided in Table 12 to Table 14. The potential for loss of containment from the well head, screw compressors and reciprocating compressors were detailed in the Hazard Identification Word diagrams and impact distances have been estimated. This analysis has not attempted to provide a full inventory of the parts (and therefore potential for leaks) of the total station infrastructure. It has focused on potential releases after each compressor.

Discussions with Project Engineers indicated that full bore ruptures of the steel pipelines were unlikely. AS 2885 and studies by the POG/APIA indicate that most damage to pipelines results from external interference, particularly excavator machinery. Therefore, the following scenarios for pipeline damage were modelled:

1. Full bore rupture for HDPE flow lines;
2. Hole size of 25mm (hole puncture (e.g. excavator) or instrument fitting); and
3. Large hole size of 150mm (see Table 11).

The pipeline lengths modelled represent worst case scenarios – e.g. maximum length from an isolation valve. Sensitivity modelling of shorter distances showed reduced impact zones.

6.2.1. Meteorological Conditions

The consequences of unplanned CSG releases were predicted using the model for Areal Locations of Hazardous Atmospheres (ALOHA) (see Section 3.4.1). The releases were modelled under a range of meteorological conditions based on average data collated from the Bureau of Meteorology for Dalby, Miles, Biloela and Gladstone. Data from Miles is most representative of the meteorological conditions in the CSG Field (i.e. gas wells, flow lines, trunklines, FCS and CPP). The UIC_Export Pipeline however will extend from Miles to Gladstone and therefore be subject to coastal conditions (such as higher wind speeds).

The meteorological data required for input to ALOHA are:

- Wind speed (m/s);
- Wind direction (e.g. N = 0°C or 360°);
- Cloud cover (expressed in tenths);
- Air temperature (°C); and
- Relative humidity.

The average meteorological data from the Miles meteorological station (Post Office) is presented in Table 22 for each parameter and comparison data from Dalby, Biloela and Gladstone is presented in Appendix C. A sensitivity analysis of the model outputs from this range of meteorological conditions is also provided in Appendix C.

Table 22: Average Meteorological Input Data from Miles Post Office

Location		Miles
Latitude (dd)		26.66°
Longitude (dd)		150.18°
Elevation (m)		302
Wind speed (m/s)	**Mean 9am (ann)**	3.1
	Mean 3pm (ann)	3.2
Dominant wind direction	**9am**	N
	3pm	SE
Cloud cover (x/10)	**9am**	3.3
	3pm	4.9
Air temperature (°C)	**Mean min (ann)**	12.2
	Mean max (ann)	27.1
Relative humidity (%)	**Mean 9am (ann)**	62
	Mean 3pm (ann)	40

ALOHA only allows modelling of one set of meteorological conditions at a time. Therefore, while data from Miles is considered representative of most field activities (CSG Field baseline conditions), a range of meteorological conditions were modelled to ensure the impacts of lower and higher wind speeds on the potential consequences of CSG releases were evaluated. The higher wind speed scenario is most relevant to the UIC_Export Pipeline, which passes near Gladstone.

The four meteorological scenarios included in the consequence modelling were:

1. CSG Field baseline morning conditions (see Table 22);
2. CSG Field baseline afternoon conditions (see Table 22);
3. Low wind speed (0.85m/s); and
4. High wind speed (5.9m/s).

6.2.2. Types of Consequences

The consequences modelled for a gas release that is not burning are:

1. Toxic area of vapour cloud – the predicted area where the ground-level toxic vapour concentration may be hazardous;
2. Flammable area of concentration cloud – the predicted area where the ground-level vapour (fuel) concentration in air is within the flammable range and can be ignited (the area where a flash fire could occur at some time after the release or the flammable vapour cloud enters an ignition source); or
3. Blast area of vapour cloud explosion – the predicted area where the blast force from the explosion is hazardous.

The consequences for a gas release that is burning (i.e. when a flammable gas catches on fire as it is released) are:

1. Thermal radiation (modelled by ALOHA); and
2. Smoke and toxic byproducts from a jet fire (not modelled by ALOHA but expected to be minimal from a coal seam gas fire).

6.2.3. Gas Production

The results of consequence modelling for releases at the wellhead are provided in Table 23 and Table 24. Table 23 presents the results of a full bore rupture at the wellhead while Table 24 provides results from a 10mm valve or gasket leak.

Information provided by Queensland Gas Company indicates the current maximum volume of gas that may be released from a well is 5000 mcf/day (based on gas potential of one well – Lauren #6). This is equivalent to 141.6 ML/day. The total gas release (Table 23) from a full bore rupture was calculated to be 3195kg for a one hour event. This result is equivalent to ~107 ML/day (assuming 100% methane), which is in the same order as the above estimate for a maximum release. The consequence results presented in Table 23 therefore present an extreme scenario. A gas release from a valve or gasket leak (i.e. 10mm leak) is more likely.

Table 23: Results of Consequence Modelling – Gas Wellhead, Full Bore Rupture[1]

Met data	Release duration (mins)	Release rate (kg/mins)	Total amount released (kg)	Threat zone (m) not burning - toxic			Threat zone (m) not burning - flammable		Threat zone (m) not burning - blast			Threat zone (m) burning			
				TEEL-3 (25000ppm)	TEEL-2 (5000ppm)	TEEL-1 (3000ppm)	60% LEL	10% LEL	70kPa	21kPa	3.5kPa	Max flame (m)	35 kW/m^2	12.6 kW/m2	4.7 kW/m2
Baseline morning	60[2]	54.2	3195	25	56	73	34	85	Not exceeded	Not exceeded	22	9	<10	10	14
Baseline afternoon	60[2]	53.6	3161	25	56	72	34	84	Not exceeded	Not exceeded	27	9	<10	10	14
Low wind speed	60[2]	54	3183	33	73	94	44	109	Not exceeded	Not exceeded	38	9	<10	10	12
High wind speed	60[2]	53.4	3153	25	56	74	34	86	Not exceeded	Not exceeded	24	9	<10	10	16

[1] Bore size = 110mm, depth = 400m, infinite source

[2] Limited to 60 minutes duration by model

Table 24: Results of Consequence Modelling – Gas Wellhead, 10mm Valve Leak[1]

Met data	Release duration (mins)	Release rate (kg/mins)	Total amount released (kg)	Threat zone (m) not burning - toxic			Threat zone (m) not burning - flammable		Threat zone (m) not burning - blast			Threat zone (m) burning			
				TEEL-3 (25000ppm)	TEEL-2 (5000ppm)	TEEL-1 (3000ppm)	60% LEL	10% LEL	70kPa	21kPa	3.5kPa	Max flame (m)	35 kW/m^2	12.6 kW/m2	4.7 kW/m2
Baseline morning	29	1.56	5.66	<10	<10	13	<10	14	Not exceeded	Not exceeded	Not exceeded	1	<10	<10	<10
Baseline afternoon	28	1.54	5.55	<10	<10	12	<10	14	Not exceeded	Not exceeded	Not exceeded	1	<10	<10	<10
Low wind speed	29	1.55	5.6	<10	13	16	<10	19	Not exceeded	Not exceeded	Not exceeded	1	<10	<10	<10
High wind speed	28	1.52	5.47	<10	<10	12	<10	14	Not exceeded	Not exceeded	Not exceeded	1	<10	<10	<10

[1] Bore size = 110mm, depth = 400m, finite source

6.2.4. Compressor Stations

Consequence modelling was conducted of gas releases from screw compressors (Field Compression Station) and reciprocating compressors (Central Processing Plant). Releases from the compressors were modelled as pipeline sources. The pipeline length was modified to simulate a release of approximately 30m^3, which is the volume expected to be released during a screw compressor start or blowdown. This gas volume was considered to be a credible release scenario assuming standard control measures, such as unit isolation valves, blow down valve and vent and pressure safety valve (PSV).

The impacts of a gas release of 30m^3 from the discharge pipeline were similar from both a screw compressor and reciprocating compressor. The primary difference was the duration of the release because of differences in temperature and pressure.

The results of these scenarios are presented in Table 25 and Table 26. The model scenario evaluated is based on a 25mm hole size, which is equivalent to a hole caused by fitting failure but conservative for a leak from a valve or flange (more likely to be 10mm).

The consequences of leaks from the pipework at the compressor stations would be similar to those modelled for the trunklines (from the FCS to the CPP) and the UIC_Export Pipeline. This was demonstrated by calculations carried out by the Zetkin Group (Process Engineers). These calculations are provided in Appendix D.

Table 25: Results of Consequence Modelling – Screw Compressor Discharge Pipe, 25mm Hole

Met data	Release duration (mins)	Release rate (kg/mins)	Total amount released (kg)	Threat zone (m) not burning - toxic			Threat zone (m) not burning - flammable		Threat zone (m) not burning – blast			Threat zone (m) burning			
				TEEL-3 (25000ppm)	TEEL-2 (5000ppm)	TEEL-1 (3000ppm)	60% LEL	10% LEL	70kPa	21kPa	3.5kPa	Max flame (m)	35 kW/m^2	12.6 kW/m2	4.7 kW/m2
Baseline morning	4	21	22.1	16	35	45	22	53	not exceeded	not exceeded	23	2	<10	<10	<10
Baseline afternoon	4	21	22.1	16	35	45	21	52	not exceeded	not exceeded	23	2	<10	<10	<10
Low wind speed	4	21	22.1	20	45	59	28	68	not exceeded	not exceeded	35	2	<10	<10	<10
High wind speed	4	21	22.1	16	35	45	22	53	not exceeded	not exceeded	21	2	<10	<10	<10

Table 26: Results of Consequence Modelling – Reciprocating Compressor Discharge Pipe, 25mm Hole

Met data	Release duration (mins)	Release rate (kg/mins)	Total amount released (kg)	Threat zone (m) not burning - toxic			Threat zone (m) not burning - flammable		Threat zone (m) not burning - blast			Threat zone (m) burning			
				TEEL-3 (25000ppm)	TEEL-2 (500036ppm)	TEEL-1 (3000ppm)	60% LEL	10% LEL	70kPa	21kPa	3.5kPa	Max flame (m)	35 kW/m^2	12.6 kW<10/m2	4.7 kW/m2
Baseline morning	1	22.14	22	16	36	47	22	54	not exceeded	not exceeded	24	2	<10	<10	<10
Baseline afternoon	1	22.14	22	16	36	46	22	54	not exceeded	not exceeded	23	2	<10	<10	<10
Low wind speed	1	22.14	22	21	47	60	28	70	not exceeded	not exceeded	36	2	<10	<10	<10
High wind speed	1	22.14	22	16	36	47	22	55	not exceeded	not exceeded	21	2	<10	<10	<10

6.2.5. Pipelines

The results of consequence modelling from the three types of pipelines are presented in Table 27, Table 28 and Table 29.

Calculations prepared by the Zetkin Group (Appendix D) are consistent with the release rates calculated by ALOHA for 1500kPa (trunkline) and 10500kPa (UIC_Export) pipelines (i.e. ~70 and 500kPa respectively).

Table 27: Results of Consequence Modelling – HDPE Flow Lines, Full Bore Rupture

Met data	Release duration (mins)	Release rate (kg/mins)	Total amount released (kg)	Threat zone (m) not burning - toxic			Threat zone (m) not burning - flammable		Threat zone (m) not burning - blast			Threat zone (m) burning			
				TEEL-3 (25000ppm)	TEEL-2 (5000ppm)	TEEL-1 (3000ppm)	60% LEL	10% LEL	70kPa	21kPa	3.5kPa	Max flame (m)	35 kW/m^2	12.6 kW/m2	4.7 kW/m2
Baseline morning	8	30.5	42.8	19	42	55	26	63	not exceeded	not exceeded	not exceeded	11	<10	10	15
Baseline afternoon	8	30	41.9	19	42	54	25	63	not exceeded	not exceeded	not exceeded	11	<10	10	15
Low wind speed	8	30.5	42.8	24	55	70	33	81	not exceeded	not exceeded	not exceeded	11	<10	10	11
High wind speed	8	29.5	41.2	19	42	54	25	63	not exceeded	not exceeded	not exceeded	11	<10	11	16

Table 28: Results of Consequence Modelling – Trunklines, 25mm Hole

Met data	Release duration (mins)	Release rate (kg/mins)	Total amount released (kg)	Threat zone (m) not burning - toxic			Threat zone (m) not burning - flammable		Threat zone (m) not burning - blast			Threat zone (m) burning			
				TEEL-3 (25000ppm)	TEEL-2 (5000ppm)	TEEL-1 (3000ppm)	60% LEL	10% LEL	70kPa	21kPa	3.5kPa	Max flame (m)	35 kW/m^2	12.6 kW/m2	4.7 kW/m2
Baseline morning	60[1]	67	2996	28	63	81	38	94	not exceeded	not exceeded	25	2	<10	<10	<10
Baseline afternoon	60[1]	66.2	2953	28	62	80	38	93	not exceeded	not exceeded	24	2	<10	<10	<10
Low wind speed	60[1]	66.7	2982	36	81	105	50	121	not exceeded	not exceeded	35	2	<10	<10	<10
High wind speed	60[1]	66.1	2948	28	63	82	38	96	not exceeded	not exceeded	23	2	<10	<10	<10

[1] Limited to 60 minutes duration by model

Table 29: Results of Consequence Modelling – UIC_Export Pipelines, 25mm Hole

Met data	Release duration (mins)	Release rate (kg/mins)	Total amount released (kg)	Threat zone (m) not burning - toxic			Threat zone (m) not burning - flammable		Threat zone (m) not burning - blast			Threat zone (m) burning			
				TEEL-3 (25000ppm)	TEEL-2 (5000ppm)	TEEL-1 (3000ppm)	60% LEL	10% LEL	70kPa	21kPa	3.5kPa	Max flame (m)	35 kW/m^2	12.6 kW/m2	4.7 kW/m2
Baseline morning	60[1]	504	29571	77	174	225	105	262	not exceeded	not exceeded	86	2	<10	15	24
Baseline afternoon	60[1]	498	29249	76	172	222	105	258	not exceeded	not exceeded	82	2	<10	15	24
Low wind speed	60[1]	502	29485	99	223	288	136	335	not exceeded	not exceeded	112	2	<10	15	24
High wind speed	60[1]	498	29254	78	180	237	108	278	not exceeded	not exceeded	81	2	<10	15	24

[1] Limited to 60 minutes duration by model

Table 30: Results of Consequence Modelling – UIC_Export Pipelines, 150mm Hole

Met data	Release duration (mins)	Release rate (kg/mins)	Total amount released (kg)	Threat zone (m) not burning - toxic			Threat zone (m) not burning - flammable		Threat zone (m) not burning - blast			Threat zone (m) burning			
				TEEL-3 (25000ppm)	TEEL-2 (5000ppm)	TEEL-1 (3000ppm)	60% LEL	10% LEL	70kPa	21kPa	3.5kPa	Max flame (m)	35 kW/m^2	12.6 kW/m2	4.7 kW/m2
Baseline morning	60[1]	16600	479746	454	1100	1400	629	1600	not exceeded	not exceeded	396	12	57	94	150
Baseline afternoon	60[1]	16400	471244	450	1000	1400	622	1600	not exceeded	not exceeded	391	12	57	93	149
Low wind speed	60[1]	16600	477497	577	1300	1600	788	1800	not exceeded	not exceeded	542	12	56	93	149
High wind speed	60[1]	16400	471485	506	1300	1800	725	2200	not exceeded	not exceeded	407	12	57	92	148

[1] Limited to 60 minutes duration by model

6.3. Effects on the Biophysical Environment

This Preliminary Hazard Assessment did not include a detailed review of the environment in which the Project Installations will be constructed nor along the pipeline routes. The landscape features however include:

- The Condamine River (flows south west);
- Clay alluvial plains, poplar box flat plains, cypress pine sands, brigalow rises, rolling downs, ironbark/bulloak forests, poplar box rises and light forests;
- Cultivated land including intensive farming and feedlots as well as low intensity grazing;
- Cultural heritage significant to the Barrunggam and Western Wakka Wakka peoples; and
- The marine environmental between the mainland and Curtis Island.

The most sensitive environments are the freshwater and marine environments. The greatest risks are associated with chemical spills of TEG and diesel. These chemicals would be stored at CPP compounds and release scenarios include failure of storage vessel or road transport accident. A road transport accident and chemical spill is considered to be the most likely scenario given expected truck movements associated with the proposed activities. Similarly fire-byproducts from a diesel spill would impact on aquatic environments if not contained.

Diesel or TEG spillage into the Condamine River or marine environment would cause local contamination of waters and sediments and short-term losses of benthic invertebrates and aquatic organisms that are unable to avoid the spill. The degree of impact on the Condamine River would depend on the freshwater flow and the volume entering the river.

On-site events causing contamination of stormwaters or firewaters should be contained by internal drainage, holding pits and bunding. On-site stormwater dams should be used for emergency management and clean up purposes to prevent any on-site losses or drainage (recommended near waterways).

Off-site overflows or major spillages from transport incidents should be contained by bunding of drainage lines, emergency clean up and remediation practices. Emergency procedures should be designed to handle spillages and fire events.

Terrestrial impacts could result from flash fire radiation, smoke inhalation by livestock and local contamination of pastures and drainage lines. Most wildlife would avoid any remnant habitats or feeding areas affected by such incidents. No significant loss of wildlife or long term contamination of soils or pastures (with the exception of a significant diesel spill causing land contamination) would be expected.

6.4. Interactions between Facilities

Possible on-site interactions exist but will be reduced by plant design and layout and separation distances. Layout and design will include reference to Australian Standards including:

- AS 1940. *The Storage and Handling of Flammable and Combustible Liquids;*
- AS 2885.1. *Pipelines – Gas and liquid petroleum. Part 1: Design and construction*; and
- AS 2430. *Classification of Hazardous Atmospheres;*

The siting of installations, such as compressor stations, must account for the potential of an accident at the station causing damage to buildings and propagating to a neighbouring operation hence initiating further hazardous incidents. The risk of offsite accident propagation in this case is low because most the surrounding land uses are rural (e.g. cattle, pastures and cotton, wheat and sorghum crops. However, the location of other major infrastructure (e.g. open cut coal mines and power stations) and storage facilities in the area (e.g. anhydrous ammonia storage providing fertilizers) need to be considered when siting installations.

The bushfire risk around the infrastructure (wellheads, compressor stations and pipelines) is low because the surrounding countryside has been cleared for pastures and grazing or cropping. Potential pasture and crop fires need to be controlled by the local Rural Fire Service.

The NSW DIPNR (2004) provides recommendations for separation distances between a CSG wellhead and residential and sensitive land use areas of approximately 10 (residential) to 20m (sensitive). These separation distances reflect the level of technical and operational controls applied to CSG wells. These guidelines may also be applied as minimum separation distances between gas wellheads in the field. The consequence model results in Table 23 and Table 24 support these recommendations.

Separation distances to gas pipelines are also provided by Shire Planning Schemes. Schedule 2 of the Murilla Shire (includes the townships of Miles and Dalby) Planning Scheme Policy for example, recommends a minimum separation distance to petroleum and gas pipelines of 200m.

The flammable vapour cloud model results provide minimum separation distances between infrastructure and adjoining land uses where the presence or use of ignition sources is outside the control of the proposed development. The model results indicate separation distances for wellheads, compressors, HDPE flowlines and trunklines as listed below:

- CSG well 109m;
- Compressor 70m;
- HDPE flow line 81m; and
- Trunkline 121m.

The potential threat zone from a flammable vapour cloud caused by a CSG release from the UIC_Export Pipeline however extends to 2200m (for a maximum hole size of 150mm and using the most conservative end point of 10% LEL).

It is recommended that these minimum separation distances be maintained between the project installation components and major infrastructure or dangerous goods storage to reduce the likelihood of interactive effects from flammable vapour clouds and ignition sources.

7. RISK CHARACTERISATION

7.1. Qualitative Assessment

The classification scheme used in this qualitative assessment was derived from AS 4360 *Risk Management* and is shown in Table 31. The consequence of fatality is considered to be either insignificant (no fatality) or major (single fatality). A qualitative assessment of the outcomes of the consequence modelling from incident scenarios involving coal seam gas releases is provided in Table 32.

The risk criterion specified by the TOR and adopted in this report as the level at which fatality occurs for instantaneous exposure is $35kW/m^2$. The consequence that is compared against this criterion is Ignition – Burning – Jet Flame. The classification of fatality therefore, is 'Insignificant' where the effect level was not exceeded or 'Major' where the effect level was exceeded.

However, Table 2 of this report indicates there is a significant chance of fatality for extended exposure at the lower level of $12.6kW/m^2$ and a high chance of injury. Extended exposure means the victim is unable to move away from the heat radiation, which might occur if someone was injured separately prior to the fire (for example). The likelihood of this scenario is considered to be low and therefore in this report, exposure to a heat radiation level of $12.6kW/m^2$ is treated as a moderate injury risk (i.e. moderate irreversible disability).

The only scenario where the effect level of $35kW/m^2$ was exceeded was a large puncture or hole to the UIC_Export pipeline, resulting in a CSG release that ignites to produce a jet fire. This scenario also presented a major injury risk.

Table 31: Qualitative Descriptions of Consequences

Consequence Table

Level	Descriptor	Example Detailed Description
1	Insignificant	Health - No medical treatment required
		Environment - Insignificant impact or not detectable
2	Minor	Health – Reversible disability requiring hospitalisation
		Environment – Potentially harmful to local ecosystems with local impacts contained to the site
3	Moderate	Health – Moderate irreversible disability or impairment (<30%) to one or more persons
		Environment – Potentially harmful to regional ecosystems with local impacts primarily contained to on-site
4	Major	Health – Single fatality and/or severe irreversible disability (>30%) to one or more persons
		Environment – Potentially lethal to local ecosystem; predominantly local, but potential for off-site impacts
5	Catastrophic	Health – Multiple fatalities, or significant irreversible effects to >50 persons
		Environment – Potentially lethal to regional ecosystems or threatened species; widespread on-site and off-site impacts

Source: AS4360:2004 and NRMMC, EPHC and AHMC (2006).

Table 32: Risks to Public based on Consequence Modelling

Scenario	Incident	Incident Outcome	Incident Outcome Case	Risk to Human Health	
				Fatality	Injury Effects
Wellhead release	Full bore release - continuous supply	No ignition - not burning	Toxic effects	Insignificant	Minor - for distances up to 94m
			Flammable vapour cloud[1]	Insignificant	Minor - isolated pockets up to 109m
			Explosion	Insignificant	Minor - for distance up to 38m
		Ignition - burning	Jet flame	Insignificant	Moderate– for distance up to 10m
					Minor - for distance up to 16m
	10mm flange or valve leak	No ignition - not burning	Toxic effects	Insignificant	Minor - for distance up to 16m
			Flammable vapour cloud	Insignificant	Insignificant - isolated pockets up to 19m
			Explosion	Insignificant	Insignificant - blast force <0.5psi
		Ignition - burning	Jet flame	Insignificant	Insignificant
Compressor release (screw or reciprocating)	25mm fitting failure	No ignition - not burning	Toxic effects	Insignificant	Minor - for distances up to 60m
			Flammable vapour cloud	Insignificant	Minor – for distances up to 70m
			Explosion	Insignificant	Minor - for distances up to 36m
		Ignition - burning	Jet flame	Insignificant	Insignificant
HDPE flow line release	Full bore release - isolated	No ignition - not burning	Toxic effects	Insignificant	Minor - for distances up to 70m
			Flammable vapour cloud	Insignificant	Minor – for distances up to 81m
			Explosion	Insignificant	Insignificant - blast force <0.5psi
		Ignition - burning	Jet flame	Insignificant	Moderate - for distances up to 11m
					Minor - for distances up to 16m
Trunklines	25mm puncture hole	No ignition - not burning	Toxic effects	Insignificant	Minor - for distances up to 105m
			Flammable vapour cloud	Insignificant	Moderate - for distances up to 50m
					Minor - for distances up to 121m

Scenario	Incident	Incident Outcome	Incident Outcome Case	Risk to Human Health	
				Fatality	Injury Effects
			Explosion	Insignificant	Minor - for distances up to 35m
		Ignition - burning	Jet flame	Insignificant	Insignificant
UIC_Export Pipeline	25mm puncture hole	No ignition - not burning	Toxic effects	Insignificant	Minor - for distances up to 288m
			Flammable vapour cloud	Insignificant	Moderate - for distances up to 136m
					Minor - for distances from 136 to 335m
			Explosion	Insignificant	Minor - for distances up to 112m
		Ignition - burning	Jet flame	Insignificant	Moderate – for distances up to 15m
					Minor – for distances up to 24m
UIC_Export Pipeline	150mm puncture hole	No ignition - not burning	Toxic effects	Insignificant	Minor - for distances up to 1800m
			Flammable vapour cloud	Insignificant	Moderate - for distances up to 788m
					Minor - for distances from 788 to 2200m
			Explosion	Insignificant	Minor - for distances up to 542m
		Ignition - burning	Jet flame	Major - for distances up to 57m	Moderate - for distances from 57 to 94m
					Minor - for distances from 94 to 150m

[1] The effects of a flammable vapour cloud igniting have not been assessed. The consequence modelling indicates the threat zone for possible ignition.

The scenarios causing major or moderate consequences were selected for further assessment using quantitative risk estimates for comparison with land use criteria. These scenarios cause heat radiation effects and are summarised below:

1. Scenarios that exceeded 35kW/m^2 (fatality)
   - UIC_Export pipeline, 150mm hole, impact up to 57m; and
2. Scenarios that exceeded 12.6 kW/m^2 (moderate injury risk)
   - Gas well head, full bore, impact up to 10m;
   - HDPE flow line, full bore, impact up to 11m;
   - UIC_Export pipeline, 25mm, impact up to 15m; and
   - UIC_Export pipeline, 150mm, impact up to 94m.

The scenarios that exceeded 4.7kW/m^2, representing minor injury risk, are listed below:

- Gas well head, full bore, impact up to 16m,
- HDPE flow line, full bore, impact up to 16m,
- UIC_Export pipeline, 25mm hole, impact up to 24m, and
- UIC_Export pipeline, 150mm hole, impact up to 150m.

The flammable vapour cloud scenarios (indicating moderate injury risk) were not evaluated quantitatively because the likelihood of ignition and heat radiation generated was unknown. The identified threat zones for these scenarios however, provide guidelines for separation distances from potential ignition sources.

7.2. Quantitative Assessment

7.2.1. Fatality Risks

The only scenario where fatality was predicted to occur was a jet fire from the UIC_Export Pipeline resulting from a 150mm puncture hole. This assessment is based on the 'worst-case' failure rate reported (0.55 per 1000km per year) and is considered conservative. Standard control measures required by Australian Standards should reduce the failure rate to that reported by Australian Industry (i.e. 0.015 per 1000km per year). A graph showing the radiation intensity with distance from the pipeline is provided in Figure 4.

The risk of fatality from the sub-surface component of the project (i.e. mainland to Curtis Island) is considered to be insignificant. However, the potential for ignition of methane gas that escapes from the water has not been assessed. The greatest risk exists where there is potential for build up of the gas in an enclosure.

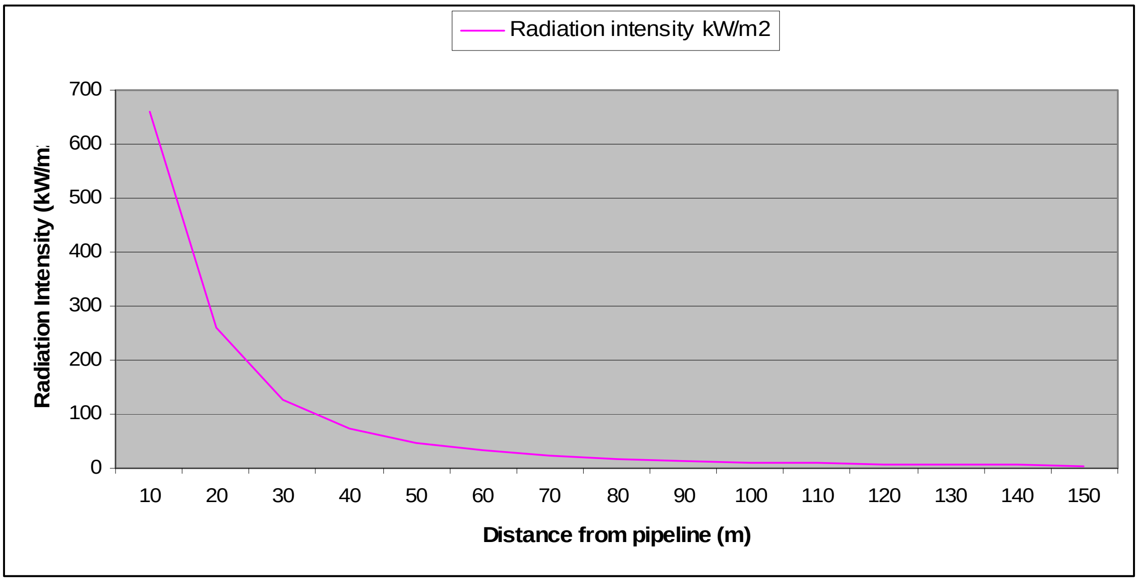


Figure 4: Radiation Intensity with Distance from UIC_Export Pipeline, 150mm hole

In the case where a fatality was predicted to occur, the risk of fatality is equal to the likelihood of the event occurring. In this case (UIC_Export pipeline, 150mm, up to 57m), the likelihood of fire was calculated to be 96 x 10^{-6} or 96 chances in million.

Fatality risk calculations at distances beyond 57m were determined using a known relationship (probit equation) between radiation intensity and probability of fatality. This type of relationship is used to derive effects criteria (e.g. Table 2) and is presented below.

The equation used for radiation intensity was taken from Lees (1996):

$$Y = -36.38 + 2.56\ln(tI^{\frac{4}{3}})$$

where t = exposure time in seconds (assumed to be 30 seconds or instantaneous), and
I = intensity of exposure in W/m^2.

The individual fatality risk transect from the pipeline is shown in Figure 5. The distances to each fatality risk criterion are summarised in Table 33.

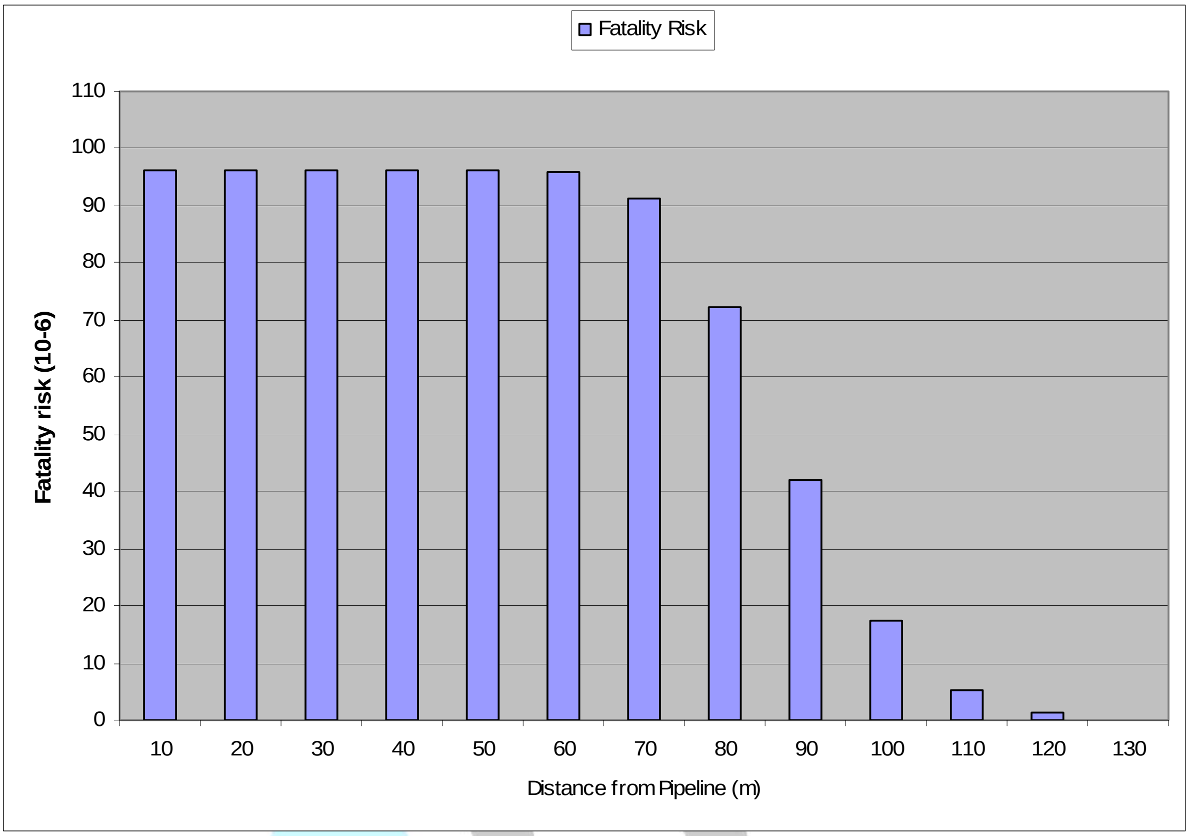


Figure 5: Individual Risk Transect Perpendicular to the UIC_Export Pipeline, 150mm hole (fatality risk per year)

Table 33: Distances to Criteria for Individual Fatality Risk (Jet Flame, UIC_Export Pipeline, 150mm Hole)

Land Use	Suggested Criteria (risk in a million per year)	Distance (m)
Hospitals, schools, child-care facilities, old age housing	0.5	126
Residential, hotels, motels, tourist resorts	1	121
Commercial developments including retail centres, offices and entertainment centres	5	111
Sporting complexes and active open space	10	104
Industrial	50	87

7.2.2. Injury Risks

The TOR requires assessment of injury risk contours at 10 and 50 x 10^{-6} per year. There is a potential for injury from either heat radiation or blast effects. Consequence modelling showed the likelihood of injuries from blast effects was very low (i.e. explosion overpressure = 0.5psi). There was however indication of injury from heat radiation (i.e. heat radiation >4.7kW/m^2) generated by a jet fire under the following scenarios:

- Gas well head, full bore, up to 16m;
- HDPE flow line, full bore, up to 16m;
- UIC_Export pipeline, 25mm hole, up to 24m; and
- UIC_Export pipeline, 150mm hole, up to 150m.

The moderate injury risks (or potentially irreversible effects) were predicted to occur at distances close to the source in all cases excluding the UIC_Export pipeline (150mm puncture) as listed below:

- Gas well head, full bore – within 10m of source;
- HDPE flow line, full bore – within 11m of source; and
- UIC_Export pipeline, 25mm hole – within 15m of source.

Moderate injury risks in the case of the UIC_Export pipeline (150mm rupture) (worst-case scenario) however, were predicted to extend to 94m from the source. This scenario therefore has been evaluated in further detail using a conservative approach because a probit equation describing the relationship between heat radiation effects and injury level was not available for this report.

Assuming the likelihood of fire equals 96 x 10^{-6} per year (see Table 21), and the probability of injury up to 94m is 1.0 (or 100%), then the risk level equals 96 x 10^{-6} per year. This exceeds the upper criterion of 50 x 10^{-6}. The injury risk level up to 150m is considered to be minor and greater than 150m is insignificant (i.e. the radiation effect level is <4.7kW/m^2). Therefore, the upper criterion is likely to be between 94 and 150m.

A similar approach can be applied to the UIC_Export pipeline 25mm hole scenario, except the moderate injury risk only extends to 15m. That is, the risk of injury at 15m from the source is 22 x 10^{-6} (see Table 21), which is below the upper criterion. In this case, the lower criterion (10 x 10^{-6}) is likely to be within 15 and 24m (when the radiation effect level is <4.7kW/m^2).

If we consider the rate of loss of containment based on Australian data, then the injury risk level at 94m would be 2.62 x 10^{-6}. This risk level is below the lower criterion of 10 x 10^{-6}. Maintaining a buffer of 94m from the UIC_Export pipeline would protect people from injury and is conservative based on this preliminary assessment. The conservative estimates of injury risk are summarised in Table 34.

Table 34: Summary of Injury Risk Levels with Distance

Scenario	Distance to moderate injury risk 12.6 kW/m^2 (m)	Conservative injury risk level (x 10^{-6})	Distance to minor injury risk 4.7kW/m^2 (m)	Estimated Distance (m) 50 x 10^{-6}	Estimated Distance (m) 10 x 10^{-6}
Gas well head, full bore rupture	10	0.2	16	na	<10
HDPE flow line, full bore	11	17[1]	16	na	<16
UIC Export pipeline, 25mm	15	22[1]	24	na	<24
UIC Export pipeline, 150mm	94	96[1]	150	57 – 150[2]	<150

1 Worst-case incident rate scenario
2 Fatality indicated up to 57m

It should be noted that these risk levels assume people are present within the threat zone for all the time (the same applies to the individual fatality risk levels).

7.3. Societal Risks

Assessment of societal risks provides a mechanism whereby the number of people exposed can be taken into account as well as the magnitude of the individual risk to each of these people. This analysis requires population presence data, which was not included in the scope of work for this preliminary assessment.

However, review of the proposed field layout and surrounding residences indicates the societal risks are likely to be highest west and southwest of Chinchilla, southeast of Wandoan and around Condamine. The societal risks along the UIC_Export Pipeline route however, are expected to be lower.

8. CONCLUSIONS

All risks are manageable with conventional safety and mitigation measures for gas wells, compressor stations and pipelines. However, risks exist because of the nature of the coal seam gas (CSG). The primary component of CSG is methane, which is a flammable gas. This means that it will ignite in air on contact with a source of ignition.

Pipeline rupture is a significant risk because when the gas dilutes in air it will go from a rich air fuel ratio to a lean air fuel ratio and pass through the explosive limit in the process. The lower explosive limit (LEL) for methane is 5% and the upper explosive limit (UEL) is 15%. If a spark is created while the air and fuel is in the explosive range, then an explosion or fire will result.

The primary outcomes of this preliminary hazard assessment were:

- The only scenario where the instantaneous effect level of $35kW/m^2$ was exceeded was a large puncture or hole to the UIC_Export pipeline, resulting in a CSG release that ignites to produce a jet fire. This scenario also presented a major injury risk;
- The consequence of a large release from the UIC_Export was predicted to result in fatality at distances up to 57m from the source. The likelihood of this event occurring (release and ignition) was calculated to range from 2.62 to 96×10^{-6}. The individual risk criterion of 1×10^{-6} per year for residential land uses was exceeded after 121m;
- The injury risk from a large release from the UIC_Export pipeline was not expected to exceed the upper criterion of 50×10^{-6} beyond a distance of 150m from the source because consequence modelling indicated no injury (i.e. heat radiation $<4.7kW/m^2$) after this point.

Potential releases from the other hazardous event scenarios were relatively minor based on the assumptions used in this report. The injury risk level associated with releases from the wellhead, HDPE flowlines and UIC_Export pipeline (25mm) for example was estimated to be limited to 24m from the source.

This preliminary analysis also provides some recommended separation distances between the Project Installations and surrounding infrastructure for more detailed analysis:

- The recommended minimum separation distance between gas wellheads in the field is 20m;
- The recommended minimum separation distance between gas wells, compressors, HDPE flowlines and steel trunklines and major infrastructure (e.g. power station) or dangerous goods stores is 115m; and
- The recommended separation distance between the UIC_Export Pipeline and major infrastructure is 2200m.

These separation distances are conservative because they do not consider the likelihood of this type of event occurring. Risks associated with blast overpressure were predicted to be very low (i.e. 0.5psi).

Risk management procedures should include prevention of off-site losses of chemicals such as TEG or diesel (in the event of a spill) to protect the Condamine River and marine environment off Gladstone.

The assessment has not considered the case for leaks from all possible parts within the FCS and CPP but has focussed on possible releases from immediately downstream of the compressor. In addition, the analysis assumed standard operating control measures, which include isolation. Both the potential for leaks based on a full parts inventory and the likelihood of a continuous release (e.g. through human error or warnings system failure) should be evaluated in further detail when detailed design information is available.

The assessment has not considered the potential for fire or explosion following a methane release to water and subsequent discharge to the atmosphere.

9. REFERENCES

- AS 1940. *The Storage and Handling of Flammable and Combustible Liquids;*
- AS 2430. *Classification of Hazardous Atmospheres;*
- AS 2885.1. *Pipelines – Gas and liquid petroleum. Part 1: Design and construction*;
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Appendix A:
List of Documents provided by Queensland Gas Company

Doc #	Date received	Title	Description
#ELP261_01	21/01/2009	Base case	Upstream (CSG Field) and Pipeline Components
#ELP261_02	21/01/2009	HAZOP FCS	Field Compression Station and screw compressors
#ELP261_03	21/01/2009	HAZOP CPP	Central Process Plant and reciprocating compressors
#ELP261_04	21/01/2009	Schematic Field Final	Drawing
#ELP261_05	21/01/2009	Terms of Reference	Section 6
#ELP261_06	21/01/2009	IAS	Section 2.3
#ELP261_07	21/01/2009	Internal Guide	QGC Hazard and Risk Assessment
#ELP261_08	21/01/2009	HAZID spreadsheet	QGC MH
#ELP261_09	21/01/2009	Sensitive receptors maps	Four maps in different formats
#ELP261_10	21/01/2009	Gas flares	Basic information
#ELP261_11	21/01/2009	Air emissions	Compressor units
#ELP261_12	21/01/2009	Air emissions	Calculations compressor units
#ELP261_13	21/01/2009	Gas Engine Details	#1
#ELP261_14	21/01/2009	Gas Engine Details	#2
#ELP261_15	21/01/2009	Compressor Drawings	1) Screw compressor side view. Height estimates for exhaust have been added to the diagram
			2) Screw compressor aerial view. Compressors are aligned so that the side marked 'width' adjoin each other.
			3) – 7) Recip Compressor Aerial View. You will need to piece these 4 panels (RCAV 1 – 4) together to get the full picture.
			8) – 11) Recip Compressor Side View. You will need to piece these 4 panels (RCSV 1 – 4) together to get the full picture. RCSV 3 has an estimate of the exhaust height.
#ELP261_16	21/01/2009	CSG Composition	
#ELP261_17	21/01/2009	Case study	PHA Hunter Valley Pipeline
#ELP261_18	21/01/2009	Case study	PHA Leaf's
#ELP261_19	21/01/2009	Guidelines for Hazard Analysis	DPI NSW
#ELP261_20	21/01/2009	Existing Lot Plan	Field Compression Station
#ELP261_21	21/01/2009	Existing Lot Plan	Central Process Plant
#ELP261_22	21/01/2009	BG QGC	Risk Evaluation Matrix

Appendix B:
Incident scenarios based on #ELP 261-03 HAZOP Notes Kenya Field Compressor Station Upgrade

Incident scenarios based on #ELP 261-03 HAZOP Notes Kenya Field Compressor Station Upgrade

Leakage of gas at the inlet manifold (inlet manifold to compressors)

- Potential leakage and local flammable gas cloud at the stub provided for connection to the generator set
- Hazardous area classification, exclusion of ignition sources

Leakage of gas through the dump system (process water from inlet manifold)

- Gas will issue from the water pipe at the pond
- Safeguards considered adequate
- The water outlet at the pond is located in the middle of the pond and a 3m hazardous zone is defined around the outlet

Leakage from instrument bridles (process water from inlet manifold – dump system instrument bridles)

- Local flammable atmosphere
- Ignition sources are excluded
- Wiring and instrumentation is in accordance with the hazardous area classification drawings

High gas flow to Field Oily Water Tank (oily water to treatment)

- Water trap failure in any oily water dump system
- Bypassing of gas to the oil water drain header and to the Field Oily Water Tank
- Discharge of gas from the vent on the Field Oily Water Tank
- The Field Oily Water Tank vent has a flame arrestor
- The vent is sized for liquid trap failure
- Electrical hazardous area classification takes venting into account

Appendix C:
Summary of Meteorological Conditions

Summary of Meteorological Conditions from Bureau of Meteorology Stations near the Export Pipeline Route

Location	Latitude (dd)	Longitude (dd)	Elevation (m)	Wind speed (m/s)		Dominant wind direction		Ground roughness	Cloud cover (x/10)		Air temperature (°C)		Inversion height (m)	Relative humidity (%)	
				Mean 9am (ann)	Mean 3pm (ann)	9am	3pm	Urban/forest	9am	3pm	Mean min (ann)	Mean max (ann)	no inversion	Mean 9am (ann)	Mean 3pm (ann)
Dalby	27.16°	151.26°	344	3	3.5	W	W	forest	3.6	5.1	12	26.8	0	69	43
Miles	26.66°	150.18°	302	3.1	3.2	S	NE	forest	3.3	4.9	12.2	27.1	0	62	40
Biloela	29.49°	150.57°	192	2.4	2.9	W	W	forest	4	5.5	13.2	29.2	0	65	41
Gladstone	23.87°	151.22°	17	4.1	5.9	NW	W	urban	na	na	18	27.2	0	64	54

Sensitivity Analysis of Meteorological Input Data – HDPE Full Bore Rupture

Met data	Release duration (mins)	Release rate (kg/mins)	Total amount released (kg)	Threat zone (m) not burning - toxic			Threat zone (m) not burning - flammable		Threat zone (m) not burning - blast			Threat zone (m) burning			
				TEEL-3 (25000ppm)	TEEL-2 (5000ppm)	TEEL-1 (3000ppm)	60% LEL	10% LEL	70kPa	21kPa	3.5kPa	Max flame (m)	35 kW/m^2	12.6 kW/m2	4.7 kW/m2
Dalby 9am	8	30.7	43	19	43	56									
Dalby 3pm	8	30.1	42.1	18	40	52									
Miles 9am	8	30.5	42.8	19	42	55	26	63	not exceeded	not exceeded	not exceeded	11	<10	10	15
Miles 3pm	8	30	41.9	19	42	54	25	63	not exceeded	not exceeded	not exceeded	11	<10	10	15
Biloela 9am	8	30.2	42.3	22	48	62									
Biloela 3pm	8	29.7	41.4	19	44	56									
Biloela calms	8	30.5	42.8	24	55	70	33	81	not exceeded	not exceeded	not exceeded	11	<10	10	11
Gladstone 9am	8	29.8	41.6	22	50	56	30	76	not exceeded	not exceeded	not exceeded	11	<10	10	16
Gladstone 3pm	8	29.5	41.2	19	42	54	25	63	not exceeded	not exceeded	not exceeded	11	<10	11	16

Appendix D:
FCS and CPP Hole Rupture Calculations

Client	QGC	Job No.	P08QGC31
Project	QCLNG	Calc No.	
Title	Rupture Calculations	Calc By	

Inputs

Pipeline MAOP	1585	kPag
Temperature	55	C
Compressibility	0.9744	At T & P specified above
Ideal Ratio of Specific Heats	1.277	
Gas Molecular Weight	16.59	g/mol

Gas Flow through an orifice:

Compressibility Factor, Z	0.9744	
Gas Specific Heat Ratio, y	1.277	
Critical Pressure Ratio, r_{crit}	1.818450117	
Absolute Upstream Pressure	1686325	N/m^2
Discharge Coefficient, C_d	0.85	
Upstream Temperature, T	328.15	K
Sonic velocity, $a_{o,}$ at T	452.248994	m/s
Gas Molecular Weight, M	16.59	g/mol
Gas Constant, R	8310	J/kg-mol/K
Flow Factor, w	0.7493005	
Rupture Diameter	25	mm
Hole Area, A	0.000490874	m^2
Discharge Rate, G_v	1.1657583	kg/s
Discharge Rate, G_v	4196.73	kg/h

Equation 3.2 in API 520

Rupture Diamter	25	mm
Rupture Radius	12.5	mm
Area	490.8739	mm^2
Ratio of Specific Heats, k	1.277	
Sonic Velocity, C	344.7973	m/s
Coefficient Discharge, K_d	0.85	
Upstream Pressure, P_1	1686.325	kPaa
K_b	1	
K_c	1	
Temperature	328.15	K
Compressibility, Z	0.9744	
Molecular Weight, M	16.59	g/mole
Discharge Flow, W	4199.10	kg/hr

Client	QGC	Job No.	P08QGC31
Project	QCLNG	Calc No.	
Title	Rupture Calculations	Calc By	

Inputs

Pipeline MAOP	10500	kPag
Temperature	55	C
Compressibility	0.8821	At T & P specified above
Ideal Ratio of Specific Heats	1.219	
Gas Molecular Weight	16.59	g/mol

Gas Flow through an orifice:

Compressibility Factor, Z	0.8821	
Gas Specific Heat Ratio, y	1.219	
Critical Pressure Ratio, r_{crit}	1.783150777	
Absolute Upstream Pressure	10601325	N/m^2
Discharge Coefficient, C_d	0.85	
Upstream Temperature, T	328.15	K
Sonic velocity, $a_{o,}$ at T	420.4112093	m/s
Gas Molecular Weight, M	16.59	g/mol
Gas Constant, R	8310	J/kg-mol/K
Flow Factor, w	0.720077584	
Rupture Diameter	25	mm
Hole Area, A	0.000490874	m^2
Discharge Rate, G_v	7.576244432	kg/s
Discharge Rate, G_v	27274.48	kg/h

Equation 3.2 in API 520

Rupture Diamter	25	mm
Rupture Radius	12.5	mm
Area	490.8739	mm^2
Ratio of Specific Heats, k	1.219	
Sonic Velocity, C	339.1414	m/s
Coefficient Discharge, K_d	0.85	
Upstream Pressure, P_1	10601.33	kPaa
K_b	1	
K_c	1	
Temperature	328.15	K
Compressibility, Z	0.8821	
Molecular Weight, M	16.59	g/mole
Discharge Flow, W	27289.90	kg/hr

Appendix E:
Consequence Table

Consequence Table

Level	Descriptor	Example Detailed Description
1	Insignificant	Health - No medical treatment required
		Environment - Insignificant impact or not detectable
2	Minor	Health – Reversible disability requiring hospitalisation
		Environment – Potentially harmful to local ecosystems with local impacts contained to the site
3	Moderate	Health – Moderate irreversible disability or impairment (<30%) to one or more persons
		Environment – Potentially harmful to regional ecosystems with local impacts primarily contained to on-site
4	Major	Health – Single fatality and/or severe irreversible disability (>30%) to one or more persons
		Environment – Potentially lethal to local ecosystem; predominantly local, but potential for off-site impacts
5	Catastrophic	Health – Multiple fatalities, or significant irreversible effects to >50 persons
		Environment – Potentially lethal to regional ecosystems or threatened species; widespread on-site and off-site impacts

Source: AS4360:2004 and NRMMC, EPHC and AHMC (2006).