1 INTRODUCTION

OCCUTECH was commissioned by Tongaat Hulett Developments to perform a risk assessment to determine risk presented for a proposed development alongside Portion 2026 of Cottonfields 1575, Canelands East Umdloti Estate, D757, Morelands Road, eThekwini Municipality, KwaZulu Natal and its potential impact (risk).

The Sasol Gas Pipeline transports Sasol gas which is a mixture containing methane (88.6% by volume) at pressure (59 Bar) through this site. This pipeline is in a servitude and passes through the site of interest. The location of the pipeline is shown in the Appendices. Sasol has a number of preventative actions and/or measures to reduce potential incidents these are discussed in the document. A release could result in

- toxic gas release. This could cause asphyxiation due to reduction of Oxygen in atmosphere.
- gas fire - jet fire
- explosion - vapour cloud explosion (VCE)

The potential of a release of gas from the pipeline is considered to be small.

The property owner wishes to develop the site. The proposed development is unknown. South Africa unlike many other countries does not have legislation which stated what risk levels are acceptable (tolerable). The Major Hazard Installation Regulations does include pipelines, but this is limited. This Sasol gas pipeline has not been declared a MHI by Sasol.

The current MHI Regulations does not specifically include pipelines. The General Regulations lists chemicals and volumes which determine that they are a compulsory MHI. Methane is listed and a volume of 15 tons is prescribed. The volume in the pipeline on this site is less than this amount under normal operating conditions. Therefore this pipeline is not an automatic MHI. This risk assessments purpose was to evaluate a worst case risk and determine if that can determine if the pipeline is an MHI.

This risk assessment evaluated the worst case scenario and alternative case scenario's. These could identify the risk should a leak occur, and where this risk could occur. This site is at present agricultural land and no buildings or persons live on this land.

The Major Hazardous Installations Regulations framed under the Occupational Health and Safety Act 1993 (Act 85 of 1993) requires management to identify if their processes or activities can constitute or cause a major hazardous incident. If it can, then a risk assessment must be performed to determine the possible consequences so that appropriate preventive measures can be implemented.

Major Hazard Potential: Release of Toxic Cloud
Worst case presents the greatest risk
Ignition of gas cloud - jet fire
- explosion (vapour cloud explosion)

2 PURPOSE

2.1 To determine the hazard and the risk presented by the Sasol gas pipeline

2.2 To enable management to comply with the legal requirements framed under the Major Hazard Installation Regulations.

2.3 To enable a management plan to be established should an incident occur.

2.4 To determine the magnitude of such an incident (worst case).

2.5 To determine the possible magnitude of incident which will present a problem (alternative case). The more likely consequence(s) if an incident occurred.

3 OBJECTIVES

3.1 To identify any specific risks.

3.2 To determine the probability and nature of a possible incident.

3.3 To determine mitigation measures to prevent, minimise or contain the effect of such an event.

3.4 To enable emergency and crisis management programs to be developed.

4 METHODOLOGY

The basic methods were to:

- To use the legislation to determine if the gas pipeline is a Major Hazard Installation on this site.
- To determine the worst case scenario for the gas pipeline and the potential area of concern.
- Both of the above, would identify the need for the performance of a risk assessment. Its purpose would be to determine what circumstances, conditions could cause or have potential to cause a major incident, accident or disaster and how these circumstances/ conditions can reduce this potential.
- Determine the individual and societal risk potential based on the worst case scenario.

4.1 Terminology and definitions

4.1.1 Emergency Plan

Emergency Plan means a written plan which, on the basis of identified potential incident at the installation, together with their consequences, describes how such incidents and their consequences should be handled on site and off site;

4.1.2 Installation

Installation also includes pipelines and containers on the premises but excludes containers in transit on a public road;

4.1.3 Local emergency service

Local emergency service means a service as defined in section 1(1) of the Fire Brigade Services Act, 1987 (Act No. 99 of 1987): Provided that where no fire brigade service is available or capable of handling or controlling a major incident the employer, self-employed person or user shall be deemed to be the local emergency service;

4.1.4 Major hazard installation

Major hazard installation means an installation where any substance is produced, processed, used, handled or stored in such a form and quantity that it has the potential to cause a major incident;

4.1.5 Major incident

Major incident means an occurrence of catastrophic proportions, resulting from the use of plant and machinery, or from activities at a workplace;

4.1.6 Material safety data sheet

Material safety data sheet means a material safety data sheet as contemplated in regulation 7 of the General Administrative Regulation;

4.1.7 Near miss

Near miss means any sudden event involving one or more hazardous substances which, but for mitigating effects, actions or systems, could have escalated to a major incident;

4.1.8 Off site emergency plan

Off site emergency plan means the emergency plan to be followed outside the premises of the installation or part of the installation classified as a major hazard installation;

On site emergency plan means the emergency plan to be followed inside the premises of the installation or part of the installation classified as a major hazard installation. This plant must include those requirements listed in Section 6 of the Major Hazard Installation Regulations;

4.1.9 Risk assessment

Risk assessment means a process of collecting, organising, analysing, interpreting, communicating and implementing information in order to identify the probable frequency, magnitude and nature of any major incident which could occur at a major hazard installation and the measures needed to be taken to remove, reduce or control potential causes, of such incident. This definition also incorporates the provisions of Section 5 of the Major Hazardous Installation Regulations;

4.1.10 Rolling stock

Rolling stock means any locomotive, coach, railway carriage, truck, wagon or similar contrivance used for the purpose of transporting persons, goods or any other thing, that can run on a railway;

4.1.11 Temporary installations

Temporary installation means an installation that can travel independently between planned points of departure and arrival for purposes of transporting any substance and which is only deemed to be an installation at the points of departure and arrival respectively and that will remain at anyone place for a maximum of 30 days whilst containing the substance that resulted in it being declared a major hazard installation; and

4.1.12 Transit

Transit includes any time or place in which rolling stock may be between planned points of departure and arrival.

4.1.13 Toxic Endpoint

A **toxic endpoint** defines the outer boundary of a concentration considered hazardous to the community. For accidents involving toxic chemicals, the distance is based on the ability of a victim to escape the area. Most people can be exposed to an endpoint concentration for one hour without suffering irreversible health effects or other symptoms that would make it difficult to escape. People within the distance to an endpoint are likely to be exposed to higher concentrations and greater hazards. Individual exposed to higher concentrations for an extended period may be seriously injured.

$$\text{Endpoint ppm} = \frac{\text{Endpoint mg/l} \times 1000 \times 245}{\text{Molecular weight}}$$

Unmitigated Release of Toxic Gas

$$QR = \frac{QS}{10}$$

QR = release rate (g per minute)

QS = quantity released (g)

Release of toxic gas in enclosed space

$$QR = \frac{QS}{10} \times 0.55$$

0.55 = Mitigation factor

4.2 Method

The risk assessment was performed in accordance with recognised principles. This included site visits, site inspection, collection of data from those involved and also included literature studies, site inspections, site interviews, research and other documentation. The consequences were calculated from worse case and alternative case(s) scenario conditions using ALOHA. The worst case and alternative case scenarios were determined to be a gas leak which ignites. The released gas could also present a health risk. The gas cloud plume was calculated using ALOHA, a computer-based program for chemical spillages and emergency planning. RMP - COMP ALOHA and AFTOX are recognised models for determining the consequence of a worst case and alternative case(s) scenarios.

5 THE SITE AND PREMISES

5.1 Location

The site is located in Canelands East. It is Portion 2026 of Cottonlands 1575. This site is flat and is to be developed into a Shopping Complex Richards Bay Shopping Complex. The site is portion of Umdloti Estate, Canelands, eThekwini Municipality (Co ordinates 29.37.17.55 S and 31.03.45.78E. The aerial photograph identify its location. The Sasol gas pipeline passes through this site and at one location a pressure reducing pump station is located. This is illustrated in Appendix 4.

5.2 Physical description of site

The current use is agricultural and the owner wishes to develop the site. This land is predominately flat.

The Sasol pipeline is underground and passes through this site. The owner of this site identified the risk associated with pipeline but wishes to develop the site.

The Sasol gas pipeline has an open servitude around the pipeline and passes through this site. Sasol also has a station on this site. The gas pipeline was originally laid in 1969 for transport of oil. In 1995 the pipeline was converted to a gas pipeline. The gas is supplied by Sasol from Secunda.

5.3 Proposed Development Descriptions

Tongaat Hulett the land owner wishes to develop the site. The end user is unknown.

5.4 Mitigation Factors

5.4.1 Sasol has a maintenance system and regular checks of this system occurs.

5.4.2 The installation of isolation block valves at key locations along the length of the pipeline route.

5.4.3 Anti cracking/fracture protection has been installed at key locations.

5.4.4 Servitude surveillance is undertaken by dedicated Supervisors and the pipeline route is also inspected by helicopter to detect and control 3rd party activity on the pipeline route.

5.4.5 Additional route markers have been installed and the actual position of the pipeline has recently been verified using GIS.

5.4.6 Cathodic Protection (CP) is rigorously applied an managed to ensure pipeline integrity by eliminating the possibility of galvanic corrosion on the pipeline.

5.4.7 Pressure monitoring is carried out along the length of the pipeline route with the pressures being indicated in the Sasol Control Room which is manned around the clock.

5.4.8 Intelligent pigging was carried out on the pipeline when it is on liquid service and the line is currently undergoing a further round of intelligent pigging to locate defects which will be repaired. The current intelligent pigging exercise on this pipeline if approximately 66% completed.

5.4.9 All employees are trained in all aspects including emergency procedures. Some employees have been trained in first aid and some in fire fighting.

5.4.10 An emergency plan is available but does not include a Crisis Management should the tanks and filling process be damaged severely. This can be added to the existing plan, and is one of the recommendations.

6 THE HAZARD

Methane gas can present a serious health risk, environmental and/or fire if unprotected exposure occurs. The primary hazard is the release of a toxic gas cloud into the outside atmosphere and the basic hazardous information for Methane is provided in Appendix 5 and some of its properties are listed below. Methane acts a simple asphyxiant when inhaled. Its presence in air displaces the air, which lowers the partial pressure of Oxygen and cause hypoxia in those who breathe it in.

<u>Methane</u>

Molecular weight:	16.04 - 17.2
Liquid Factor Boiling (LAB):	-
Density Factor (DF) Boiling:	-
Gas Factor (GF):	-
Vapour Pressure at:	258574 mm Hg at 100.0ºF: 760 mm Hg at -258.7ºF
Vapour Density (Air = 1):	0.55 - 0.59
Immediately dangerous to life or health (IDLH):	No specifications
Occupational Exposure Limit OEL-RL TWA	No exposure limit in South Africa, USA ACGIH 1000 ppm Aliphatic hydrocarbon gases Alkane (C1 - C4)
STEL	
Odour :	Colourless, odourless Mercaptans can be added to provide odour
Ambient Boiling Point	-161.5ºC
Freezing Point	-182.5ºC
Odour Threshold:	Not available (according to Sasol MSDS)
Flash Point:	-223°C (369ºF)
Lower Explosive Limit:	5.0% (50 000 ppm)
Upper Explosive Limit:	15.0% (150 000 ppm)
Auto ignition:	537ºC (999ºF)

Emergency Response Guidelines

PAC-1: 2 900 ppm
PAC-2: 2 900 ppm
PAC-3: 17 000 ppm

The PAC levels replaced the TEEL levels in 2012. PAC - Protective Action Criteria for chemicals is a hierarchy based system of the three common public exposure guideline systems AEGL, ERPG's and TEEL'S.

PAC-1 is the airborne concentration (expressed as ppm [parts per million] or mg/m³ [milligrams per cubic meter]) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, these effects are not disabling and are transient and reversible upon cessation of exposure.

PAC-2 is the airborne concentration (expressed as ppm or mg/m³) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting, adverse health effects or an impaired ability to escape.

PAC-3 is the airborne concentration (expressed as ppm or mg/m³) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening adverse health effects or death.

This level identifies the level is in the flammable range (10 - 49% of LEL).

TEEL-1: 3 000 mg/m³
TEEL-2: 5 000 mg/m³
TEEL-3 : 200 000 mg/m³

TEEL-0 is the threshold concentration below which most people will experience no adverse health effects.

TEEL-1 is the airborne concentration (expressed as ppm [parts per million] or mg/m³ [milligrams per cubic meter]) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, these effects are not disabling and are transient and reversible upon cessation of exposure.

TEEL-2 is the airborne concentration (expressed as ppm or mg/m³) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting, adverse health effects or an impaired ability to escape.

TEEL-3 is the airborne concentration (expressed as ppm or mg/m³) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening adverse health effects or death.

TEELs are intended for use until AEGLs or ERPGs are adopted for chemicals. Methane has no AEGL and no ERPG levels.

7 RISK ASSESSMENT

The Major Hazard Installation Regulations framed under the Occupational Health and Safety Act 1993 (Act 85 of 1993), requires the employer to perform certain tasks. These are listed below:

7.1 An employer shall carry out a risk assessment at intervals not exceeding five years and submit such risk assessment to the chief inspector, relevant local government and provincial direction.

7.2 The employer shall make available on the premises a copy of the latest risk assessment for inspection by an inspector.

7.3 An employer shall in the case of an existing installation, carry out a risk assessment within 60 days, of promulgation of these regulations. (30 July 2001)

7.4 An employer shall ensure that the risk assessment as contemplated in sub regulation (1), shall:

7.4.1 Be carried out by an Approval Inspection Authority which is competent to express an opinion as to the risks associated with the major hazard installation; and

7.4.2 At least include:

7.4.3 A general process description of the major hazard installation;

7.4.4 A description of the major incidents associated with this type of installation and the consequences of such incidents, which shall include potential incidents;

7.4.5 An estimation of the probability of a major incident;

7.4.6 A copy of the on site emergency plan;

7.4.7 An estimation of the total result in the case of an explosion;

7.4.8 An estimation of the effects of thermal radiation in the case of fire;

7.4.9 In the case of toxic release, an estimation of concentration effects of such release;

7.4.10 The potential effect of a major incident at one major hazard installation or part thereof on an adjacent major hazard installation or part thereof;

7.4.11 The potential effect of a major incident on any other installation, members of the public, which includes all persons outside the premises of the major hazard installation and on residential areas;

7.4.12 Meteorological tendencies;

7.4.13 The suitability of existing emergency procedures, for the risks identified;

7.4.14 Any requirements as laid down in terms of the Environmental Conservation Act, 1989 (Act No. 73 of 1989); and

7.4.15 Any organisational measures that may be required.

7.5 An employer, and user shall ensure that the risk assessment reviewed forthwith if:

7.5.1 There is reason to suspect that the preceding assessment is no longer valid;

7.5.2 There has been a change in the process involving a substance resulting in the installation being classified a major hazard installation or in the methods, equipment or procedures in the use, handling or processing of that substance; or

7.5.3 After an incident that has brought the emergency plan into operation or after near miss.

This update risk assessment must be submitted to the Chief Inspector within and to Local government and provincial direction with 60 days.

8 ANALYSIS

The worst case analysis for the Methane release was performed. This was performed using USA EPA ALOHA. Methane releases can present one of the following:

- a toxic risk.
- fire risk

The requirements for Major Hazardous Risk Assessments are that, a worst case scenario must be determined. All controls and systems used and designed to prevent or mitigate against such a release can be considered if these fall into the active control category. All passive controls can be noted but cannot be used to mitigate the risk. The toxic endpoint for the release of all methane gas was determined. This identified that the worst case consequence varies according to the different models and how the loss occurs. USA EPA ALOHA identifies three types of worst case scenarios

- toxic
- flammable and/or (vapour cloud)
- explosive risk

The toxic risk was identified as the primary risk.

9 CONSEQUENCE ANALYSIS

To assess the potential risk, the existing pipeline with its existing mitigational measures were assessed. The potential worst case and other releases were determined. The area of development is illustrated in the Appendix 4.

The actual development of this site is unknown. It is likely to be industrial or commercial. In order for the development of the land to be granted approval the owners Tongaat Hulett must submit an Environmental Assessment (EIA). Part of this EIA is to evaluate the potential safety and health risks with respect to major hazard installations in the vicinity of the proposed development. As a result of the gas pipeline traversing this site and MHI Risk Assessment is required. This will enable appropriate Town Planning decisions to be made.

The worst case consequence for a variety of users was considered and their suitability.

9.1 Major Incidents

No previous spillages or releases of Methane from this pipe have occurred in this area. A significant release of Methane gas would result in a toxic vapour cloud being generated and released. This could be flammable and could ignite. This cloud depending on wind direction could affect all those employees on site if unprotected, and under worse case conditions would spread for a distance of at least 190 m. This was without mitigational measures.

9.2 Potential incident(s)

9.2.1 Existing pipeline

Release of toxic cloud (Methane) without ignition, and/or a gas release which ignites. Two potential ignition scenarios exist - jet fire and/or vapour cloud explosion. The greatest risk to people around a pipeline which has ignited is the exposure to thermal radiation.

9.2.2 Pipeline with existing mitigation measures

The pipeline is underground and is in a servitude. The pipeline servitude is annually monitored on foot using gas detectors. During this inspection the foliage cover/growth is also monitored. Dead patches indicate gas leaks. In addition to this inspection, overhead helicopter inspections occur. This is performed once a month in rural areas and twice a month in urban areas. Pigging also occurs 6 monthly.

9.3 The consequences of such incidents

9.3.1 Worst Case

The consequence's analysis for methane level, under worst - case conditions without mitigational measures implemented would be:

9.3.1.1 Existing Pipeline

The Sasol gas pipeline is a carbon steel pipe 547.2 mm in diameter and has a wall thickness of 9.53 mm. The pipeline is underground. This depth varies but is usually ± 1.5 m. The operating pressure is ± 50.7 bar well below the design limit of 100 bar.

A full bore rupture of the 47.5 cm pipeline will result in gas escaping and this gas would present a risk around the release point. According to Sasol should a release occur it would take at least one hour to stop the release. To stop a release two manual valves will be closed. The principal areas around the pipe are:

- agricultural land usually under sugar cane
- the R102
- access road to Chem Spec
- access road to Umgeni Hazelmere Water Works
- King Shaka airport
- iDube IDC

A full bore release will release 84 200 kg/minute of methane. In one hour it was calculated that 1.289 920 kg of methane would have been released and could ignite. This would present a significant risk to those exposed.

The gas could present a health risk to those exposed. The gas is mostly Methane (82.5 - 94.0%) and therefore presents an asphyxiant hazard at the source. The extent of the full bore gas release was calculated. These are provided in the table below and in Appendix 6.

Table 1: Area of concern - Full bore release

Consequence	Climatic conditions	Area of concern (m)
Full bore release	Stability Class F Relative humidity 50% Wind speed 1.5 m/s	190 m (1% fatality) 170 m (2nd degree burns 60 sec)

This gas once released can ignite. Two potential scenarios can occur.

- A jet fire
- or a vapour cloud explosion

Table 2: Jet Fire Radi

Radiation level (kw/m²)	Area of concern (1.5 m/s F)	Fatality
4.0	190 m	1%
12.5	106 m	10%
37.5	54 m	99%

Table 3: Jet Fire Radi - HSE Requirements

kw/m²	Zone	Area of concern (m)
8.3	Outer	132 m
13.9	Middle	100 m
21.6	Inner	78 m

A vapour cloud explosion will effect an area of:

Table 4: Vapour Cloud Explosion

Vapour Cloud Explosion			
Overpressure level of concern		Distance from Release Point (Area of Concern)	
0.07 Bar	HSE Outer Zone	1.5 m/s F	This level was not exceeded
0.14 Bar	HSE Middle Zone		
0.6 Bar	HSE Inner Zone		

9.3.1.2 Pipeline with existing mitigational measures

The client must liaise with Sasol and thereafter may implement mitigational measures.

- Enclosure of the pipeline
  Covering the pipeline with soil greater than 1.22 m will provide a reduction factor of between 0.2 to 0.7.

- The pipeline was designed to transport oil at a higher pressure. The methane gas pipeline operates at 59 Bar (754.6196 psia).

- The pipeline thickness (10.31 mm) this will also provide a reduction factor of at least 0.2.

- The developer will ensure that all windows/glazing facing the pipeline will be provided with shatterprufe/safety glass.

- The developer will ensure that all ventilation systems (air conditioners) will be located away from the pipeline.

- The developer and user will ensure that escape routes from within the building will be away from the pipeline.

Using the above the risk will be reduced to HSE Outer Zone (1×10^{-7}) on this site. HSE Inner Zone (1×10^{-5} fatalities per year) does not exist for Sasol Gas Pipeline. HSE Middle Zone (1×10^{-6} fatalities per year) will impact on this site.

The proposed mitigation measures will:

- Contain and prevent a gas release
- Allow for evacuation
- Reduce the risk of fire and prevent a vapour cloud explosion on this site

9.3.2 Alternative Case Scenario

The worst case scenario is used to determine the magnitude of the worst type of incident. These have a low probability and alternative (more likely) scenarios are determined to identify areas of concern and also the potential type of emergencies and this enables appropriate emergency plans to be drawn up and implemented. The additional controls envisaged will either prevent and contain a gas release or resist the effects of thermal radiation on persons in the risk zone (thermal radiation without mitigation). The owner/developer will need to liaise with Sasol to determine the best solution.

9.4 **Consequence**

To perform the risk assessment data relating to pipelines, failure rates, terrain, meterological data, proposed developments and the surrounding activities including those potentially at risk to be considered.

9.4.1 Pipeline data

Sasol has severe pipelines covering South Africa. The pipeline which passes through this site was installed some years ago (1995). It was designed to American Standards (ASME B31.4) and to transport crude oil at a high pressure.

This product change resulted in an upgrade, and the pipeline complied to the ASME 31.8.

Sasol is a recognised expert in management of cross country pipelines. This pipeline transports Sasol gas (88.6% Methane) from the Sasol Plant to Durban. The pipeline is 47.5 cm diameter. On this site the pipeline is between 1.5 and 2.0 m below the ground surface.

Methane is primarily a flammable risk.

9.4.2 Failure rate data

Failure rate data used is based on historical frequencies of incidents/accidents to pipeline world wide. The Dutch and HSE data is primarily used.

Table 5 provides summary of historical pipeline failure data from some of the best sources of data for onshore pipeline systems. All these sources provide raw data on failure incidents and pipeline length and an analysis of the failure causes. The most relevant and up to date databases available are those of:

- CONCAWE,
- European Gas Pipeline Incident Data Group (EGIG),
- US Department of Transportation (US DoT).

Table 5: Comparison of Various International Pipeline Failure Data

Source	Period	Overall (i.e. unmodified) Failure Frequency (per km.year)
CONCAWE	1971 - 2010	3.5 E-4*
	1981 - 2010	2.8 E-4*
	1991 - 2010	2.4 E-4*
	2001 - 2010	2.2 E-4*
EGIG	1970 - 2010	3.5 E-4
	1981 - 2010	2.9 E-4
	1991 - 2010	2.0 E-4
	2001 - 2010	1.7 E-4
US DoT, Liquids	1988 - 2001	4.9 E-4
	2002 - 2011	4.5 E-4
US DoT, Natural Gas	1988 - 2001	7.2 E-5
	2002 - 2011	1.1 E-4

* These frequencies have been filtered to include those only from the cross country sections

The CONCAWE database applies to crude oil and petroleum pipelines that are located in Western Europe, although since 2001, pipelines from a number of Eastern European countries have also been included in the database. Data is collected for the pipeline network every year. A number of figures are provided in Table 1 that show that the general trend of pipeline incidents is decreasing.

EGIG has compiled data collected by a group of 15 major gas transmission operators in

Western Europe over the period 1970 to 2015. Failure rates for the whole of this period are provided in Table 5, but again more recent data show that the performance of gas pipelines has generally improved.

In particular for gas pipelines, serious impact is most likely if there is a bore rupture; this is generally ‘unzipping of the pipeline’ such that a complete section is lost and gas is released from both ends, initially at a very high release rate. If the failure mode is accompanied by ignition, or if ignition occurs during the early part of a release, then a catastrophic fire may ensue. (If ignition is delayed, there may still be a major fire, although much of the early inventory will be lost as the pipeline rapidly depressurises).

Generic or industry standard failure probabilities for valves, pumps, etc are based on appropriate operation under an industry standard maintenance regime, which may be different from that prevailing at a site. Use of such data in risk calculations in a safety report should therefore be justified.

9.4.3 Consequence analysis

Consequence analysis was performed using the available data and the results(s) was determined to identify potential risk areas and the solutions where feasible. The potential consequences were identified, this includes:

- Toxic releases
- Jet fires
- Flash fires
- Vapour Cloud Explosions (VCE)

To determine these the terrain, meterological data, the chemical and the circumstances of the release, mitigational measures and health data is necessary and included in the evaluation.

The HSE recommends four failure sizes to consider. These were:

- 25 mm release
- 40 mm release (50% of the failure frequency)
- 110 mm release (50% of the failure frequency)
- total pipe failure (same frequency as a rupture)

The above were modelled using two weather conditions.

- Inversion with a wind speed of 1.5 m/s
- Neutral with a wind speed of 5 m/s

Table 6: Potential pipeline releases and % fatalities within the release zones

No	**Hazardous Event**	**Consequence**	**Exposure**	**Maximum distance from source m**		
				1%	**10%**	**99%**
1	High pressure gas pipeline release Hole size 25 mm	Toxic effect	Concentration			
		Explosion	Overpressure	13	10	10
		Jet Fire (F1.5)	Thermal radiation	13	10	10
		Jet Fire (D5)	Thermal radiation	13	10	10
2	High pressure gas pipeline release Hole size 40 mm	Toxic effect	Concentration			
		Explosion	Overpressure			
		Jet Fire (F1.5)	Thermal radiation	16	10	10
		Jet Fire (D5)	Thermal radiation	16	10	10
3	High pressure gas pipeline release Hole size 110 mm	Toxic effect	Concentration			
		Explosion	Overpressure			
		Jet Fire (F1.5)	Thermal radiation	28	16	10
		Jet Fire (D5)	Thermal radiation	28	16	10
4	High pressure gas pipeline release Rupture (worst case)	Toxic effect	Concentration			
		Explosion	Overpressure			
		Jet Fire (F1.5)	Thermal radiation	146	79	36
		Jet Fire (D5)	Thermal radiation	150	83	37

The above indicates the potential risk for persons in the open. It does not include the likelihood of the event happening. The severity of these effects is shown in the aerial photographs.

9.5 <u>Climatic Conditions</u>

The climatic conditions were obtained from the Weather Bureau, Durban, Department of Environmental Affairs and Windfinder. These charts are provided in Appendix 7.

The prevailing winds are north east and south west.

The temperatures fluctuate and can be as high as 35°C air temperature.

The worst case conditions would be during inversion with little to no wind.
This type of condition can occur. Its greatest prevalence would be in winter and in early morning.

9.6 Cost associated with such a Incident (Estimated loss)

For the purpose of this assessment, the worst case scenario is assumed.

9.6.1 Replacement, repair of installation

9.6.2 Indirect costs/losses

9.6.2.1 Evacuation of the site

9.6.2.2 Loss of use of site

9.6.2.3 Insurance costs

9.6.2.4 Litigation costs

9.6.2.5 Hospital and other medical costs

10 RISK DETERMINATION

10.1 Identification of risk (threat)

The first phase of a risk assessment is to identify where materials, equipment, activities, processes, operations have the potential to do harm. The pipeline, the existing controls and the potential proposed land usage needs to be considered. The risks were identified for the proposed development and the existing pipeline. The layout of the proposed development is provided in Appendix 4. The total number of persons on this site is unknown but it could exceed 5000 at times.

The primary activities on these sites at this time are unknown. The activities /processes and chemicals used/stored is unknown and the end user may have to conduct a MHI Risk Assessment. The MSDS of the gas is provided in Appendix 8.

10.2 Likelihood of Occurrence

When all threats (hazards) have been identified, the likelihood of the hazard causing a risk must be determined. The frequency of their occurrence is estimated, usually from relevant historical data.

For process industries, the initial incident usually involves a loss of containment of some sort - a leak (pipe, flange) or tank leak. For pipelines a release of gas (loss of containment) can also occur. A variable number of potential failure modes can arise. The failure modes of the hazard are categorized, and all contributing components are identified.

Table 7

Potential Failure Components	Hazardous Event
Pipeline failure - full bore - smaller aperture	Minor to major leak - major release - minor release

The pipeline failures have occurred, these are not common. This pipeline is also underground encased with soil. The pipeline design also adds to the low risk and failures.

The UK and American pipeline data was used to determine the frequency of a pipeline release.

The EGIG has collected data for many years on the primary failure frequencies for pipelines. The table below lists the pipeline failure frequencies.

Table 8: Primary Frequency Failures

Period	**Interval**	**Number of incidents**	**Total system exposed (km-yr)**	**Primary failure frequency per 1000 km-yr**
1970 - 2007	7th report 38 years	1173	$3.15.10^{6}$	0.372
1970 - 2010	8th report 41 years	1249	$3.55.10^{6}$	0.351
1971 - 2010	40 years	1222	$3.52.10^{6}$	0.347
1981 - 2010	30 years	860	$3.01.10^{6}$	0.286
1991 - 2010	20 years	460	$2.25.10^{6}$	0.204
2001 - 2010	10 years	207	$1.24.10^{6}$	0.167
2006 - 2010	5 years	106	$0.654.10^{6}$	0.162

The results indicate a reduction in the failure rates.

The primary failure causes was also determined. External interference remains the main cause of incidents. The table 9 below lists the uses.

Table 9: Causes of pipeline failure

Cause	%
External interference	48.4
Construction defect/Material failure	16.7
Corrosion Ground movement	16.1 7.4
Hot tap made by error	4.8
Other and unknown	6.6

10.3 Consequence Assessment

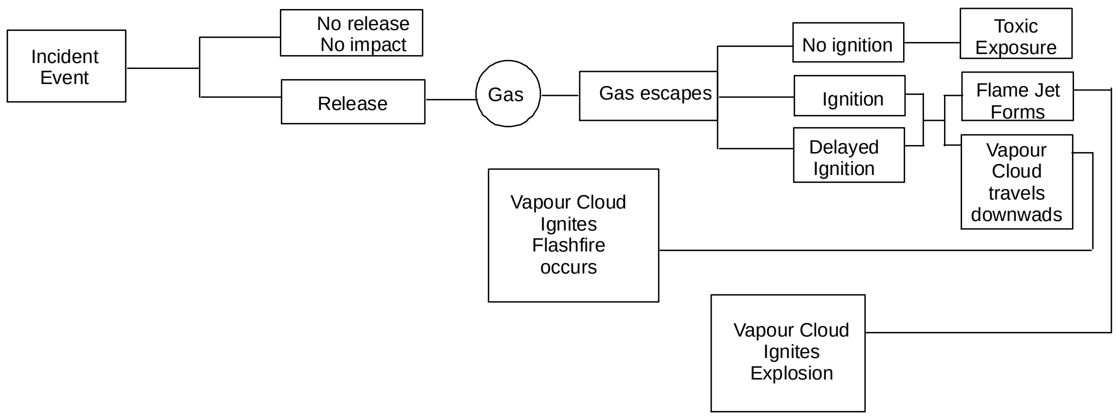
Once the likelihood, and the potential source of failure have been identified (or considered), the possible consequences (outcomes) of each failure need to be considered.

This is dependent upon many factors.

- the material released, its hazards
- the existence of operational mitigation measures (automatic or manual detection and isolation)
- the potential for the event escalating (toxic release igniting)

The Event Tree Analysis approach was used to determine this. The event tree starts with a hazardous event, which is one of the failure modes (pipe leaks). The branches with each fragmentation represent an intermediate event (ignition of flammable material). To establish the risk, each branch is assigned a probability, with the end of the tree representing the probabilities' distribution outcomes. This is illustrated in Figure below.

Figure 1:



The material in the pipeline is methane gas. This gas is colourless, odourless and is highly flammable. It is an asphyxiant. The pipeline has many safety features. These are discussed in detail in other sections of this report.

Research has identified that most pipeline releases do not ignite. Without ignition the toxic risk is reduced and for more releases it primarily effects the immediate surroundings - kills plants/vegetation and could affect someone in that area.

Most of the consequences is when the gas ignites. EGIG identifies the ignition risk from a gas leak to be 4.5 %. Ignition depends on the existence of random ignition sources. The EGIG data identifies that a hole in the pipeline had the low risk of ignition 2% whilst a rupture (worst case) had a higher ignition potential (13%).

Ignition by lightning was identified to be a cause of more than 50% of the gas releases recorded by EGIG between 1970 and 2010.

The EGIG data evaluated 1249 incidents with regard to pipelines. Only 7 cases resulted in fatalities. Fatalitites to the public only occurred in 2 cases (0.2% of the population). Incidents caused by external interference and ground movement were characterized by potential severe consequences.

10.4 Frequency analysis

The gas pipeline was constructed to transport other fuel and also to handle higher pipeline pressures. The current pipeline failure rates were taken from a variety of databases on pipeline failures CONCAWE, European Gas Pipeline Incident Data Group (EGIG), USA Department of Transport (US DoT) reference books. These rates are discussed in this report. The table below is a total illustrates some of the potential failure rates.

Table 10: Comparison of Various International Pipeline Failure Data

Source	Period	Overall (i.e. unmodified) Failure Frequency (per km.year)
CONCAWE	1971 - 2010	3.5 E-4*
	1981 - 2010	2.8 E-4*
	1991 - 2010	2.4 E-4*
	2001 - 2010	2.2 E-4*
EGIG	1970 - 2010	3.5 E-4
	1981 - 2010	2.9 E-4
	1991 - 2010	2.0 E-4
	2001 - 2010	1.7 E-4
US DoT, Liquids	1988 - 2001	4.9 E-4
	2002 - 2011	4.5 E-4
US DoT, Natural Gas	1988 - 2001	7.2 E-5
	2002 - 2011	1.1 E-4

* These frequencies have been filtered to include those only from the cross country sections

11 INDIVIDUAL RISK CALCULATION

Individual Risk is usually restricted to the site, and only if the area of concern exceeds the site boundaries and also if the person(s) are permanently in that area (a building which is occupied) will they be included in the risk. It is defined as “The risk to a person in the vicinity of a hazard”. This includes the nature of the injury to the individual, the likelihood of injury occurring and the time period over which the injury might occur (CPPS 1989)

The potential areas of impact (concern) were calculated using ALOHA.

The determination of the impact of an incident requires two steps. The first step estimates a physical concentration of the material or energy at each location (A toxic release and its concentration or radiant heat from a fire). The release which ignites was identified as the primary risk.

The second step estimates the impact that this incident /accident occurrence has on people, the environment and/or property.

The individual risk in the impact zones is:

- Explosions. All persons within the impact zone are killed (probability of fatality = 1.0), all persons outside of this zone or beyond the impact zone distance are unaffected (probability of fatality = 0)

- Toxic emissions/releases. All persons within the area of concern will die (probability of fatality = 1.0) all persons outside of the area of concern (plume) no death occurs (probability of fatality = 0).

- Thermal effects. All persons within exposed to thermal radiation are at risk. Those exposed to levels above 37.5 kWm2 of thermal will die, whilst those exposed to low levels may be affected.

Individual risk is the probability that an individual at a particular location could be killed by an incident (the worst case for Methane according to RMP Comp is a toxic vapour cloud release), during a particular time period, usually a year. In order to carry out the calculation, the following information should be available. RMP Comp lists a lower leak, release than the total volume stored as an alternative case scenario.

In assessing Major Hazardous Installations an estimate of the extent (ie. the hazard ranges and widths) and the severity (ie. How many people are affected, including the number of fatalities) of the consequences of each identified major accident hazard. For an evenly distributed population, the number of fatalities resulting from a toxic release may be approximated by the estimating the number of people inside the concentration contour leading to an LD50 dose (ie. SLOD DTL). The approximation results from the assumption that those people inside the SLOD contour who did not die (due to factors such as physiology, fitness levels) will be balanced by a similar number outside the SLOD contour who do die again due to a variety of factors (age, state of health).

Methane has no LD and is an asphyxiant. Its primary risk is flammability and the thermal radiation released from the ignited gas. Methane is highly flammable.

In assessing the risk and those exposed, the proportion of those exposed indoors must be included. Those indoors will be provided a degree of protection against the effects of the release. The level of protection is related to the rate at which air and toxic material enters the building and maybe measured by air changes per hour.

Risk Assessments must consider both the consequence (severity) and the likelihood or frequency of each major accident.

11.1 Frequency of incidents

Many techniques are available to estimating the frequency of incidents. These include:

- fault tree analysis
- event tree analysis
- historical incident data

The frequency of a pipeline explosion is low 1 x 10^{-6} event per year. The potential frequency of a toxic release from a pipeline is also low, but slightly higher than an explosion is 3 x 10^{-5} events per year. The probability of ignition of flammable release from a pipeline is 4%.

The EGIG Report 2011 calculated the ignition probability to be 4.5% for the pipelines in Europe. This report also provided data between leak size and possibility of ignition.

Table 11: Ignition probability

Size of leak	Ignition probabilities %
Pin hole crack	4
Hole	2
Rupture	13

Ruptures which ignite can cause severe societal damage. The EGIG data also identified that big pipelines are more likely to ignite than smaller diameter pipelines. Large pipelines are also likely to be at higher pressure.

Table 12: Larger pipelines ignition probability

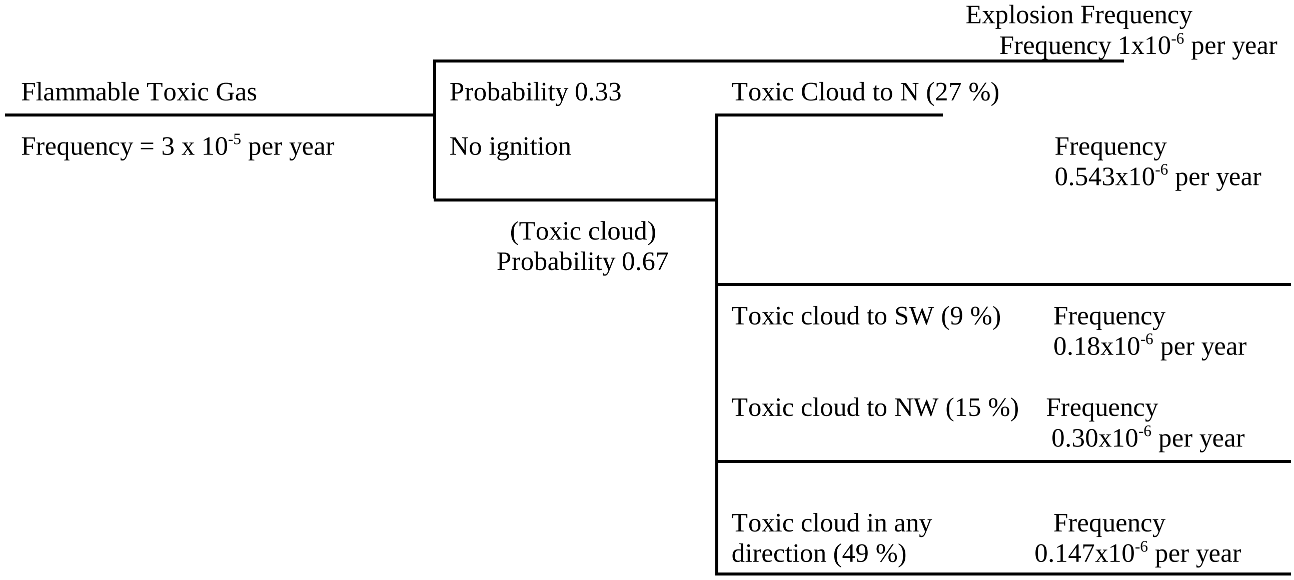
Size of leak	Ignition probability %
Rupture <16 inch	10
Rupture > 16 inch	33

The EGIG also considers lightning as a source of ignition. Out of the 21 gas releases between 1970 and 2010 12 ignited due to lightning (57%).

The historical incidents data for the Sasol gas pipelines identifies no accidents or incidents over the last five years. Data from other countries is included in the Appendix 9. This identifies a number of incidents and fatalities which would fall into this assessment.

Figure 2

FREQUENCY OF AIR GAS RELEASE



Note: The wind rose calculated from Durban Weather Bureau was used to calculate this.

In determining the risk, those conditions/factors which can initiate the incident/accident must be considered. These factors are provided in Table 6.

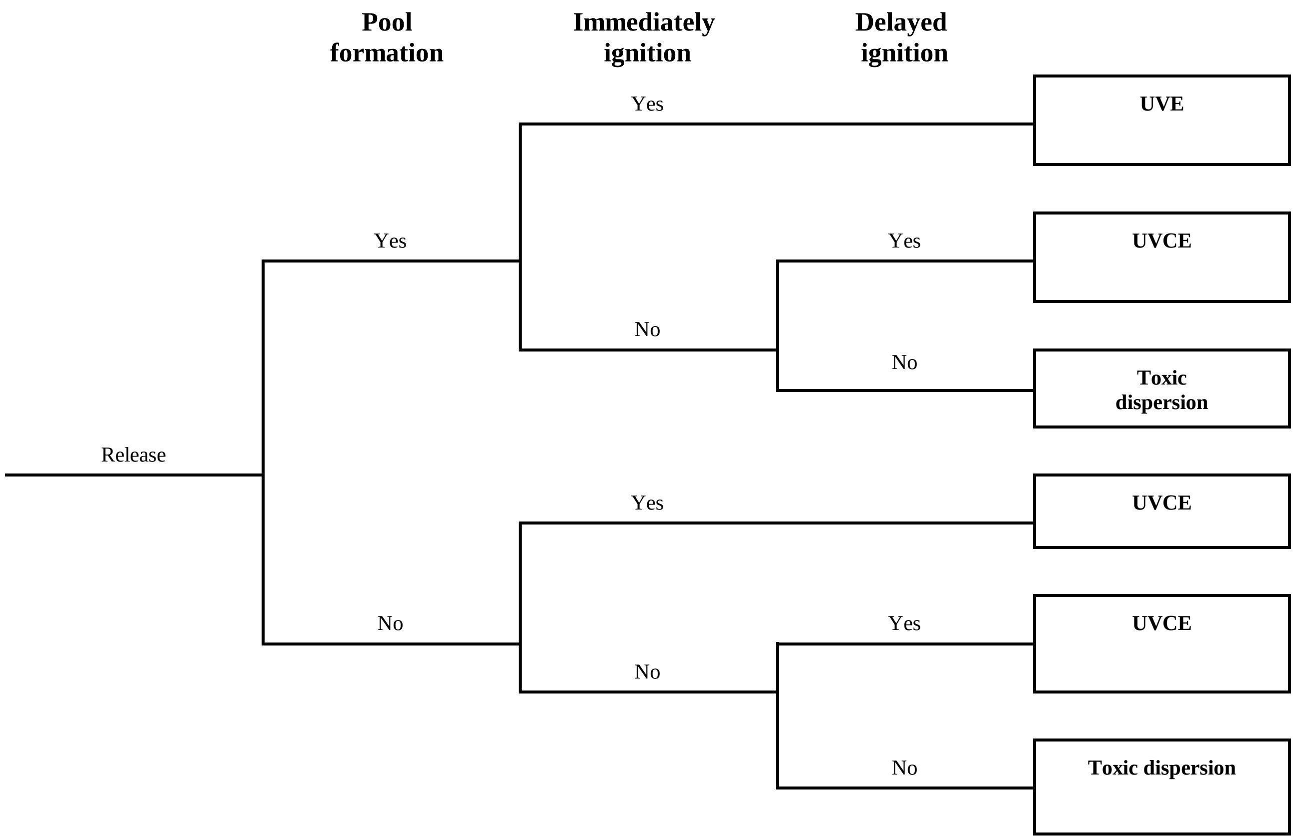
Table 13: Accident Initiators Requiring Consideration in a Safety Report

Off site Events	Operator Error	Abnormal Load	Arson or Sabotage	Inadequate Management	Loss of Service
Aircraft impact	system opened	impact by vehicle	fire	corrosion	Loss of electricity
Seismic event	filled when not closed	impact by missile	explosion	erosion	loss of cooling water
Subsidence	system overfilled	impact by dropped load	valve opened	vibration failure of process control	loss of nitrogen
Extreme environmental conditions - abnormal rain fall - abnormal snow fall - very low temperature - high temperature - flooding - gale force winds - lightning strike	containment degraded	internal temperature or pressure outside design limit	safety system degraded	cyclic load inadequate materials or specification	loss of compressed air
Vehicle/train impact	excess load	external temp/ pressure outside design limit	contamination	inadequate materials or specification	loss of steam
Land slip	failure to respond correctly to an alarm	pressurisation	control system degraded	chemical attack	
Explosion	incorrect valve action	under pressure	containment system degraded	hidden defect in containment system	
Fire				failure to detect dangerous situation	
Missile				failure of process controls	
Pipeline rupture					

"All safety critical events and associated initiators should be identified." Safety critical events are those that dominate the risk at different distances from the plant. For pressurized storage vessels, the event with the greatest hazard range is usually a fireball resulting from immediate ignition of an instantaneous release to atmosphere of the whole contents. The safety critical events for shorter distance are those occurring, the most frequently occurring and rise to the particular hazard range.

The gas pipeline has a low potential of occurrence, however, if a release occurs the risk will vary. The following could occur - gas release. This at the source it can be a health risk, the gas could ignite and present a significant safety risk.
The potential release and incident outcomes from a Methane leak is illustrated below.

Figure 3: Potential event sequences and incident outcome for Methane release.



UVCE = Unconfined Vapour Cloud Explosion

11.2 Severity

The number of potential fatalities and injuries that could result from a Major accident is determined by:

- number of people employed on site
- number of people in the surrounding area

This site is an agricultural land use area. The number of persons on this site is low. No permanent structures are on site and employees are only on site to cultivate the land and during cane cutting.

The surrounding land includes agricultural land, and industrial development, a water works and a road.

The industrial site at present has few employees on site. Chem Spec has recently closed operations. Dow Chemicals has ± 100 employees spread over 24 hours. The Umgeni Water Works has 30 - 40 employees also spread over 24 hours.

The nearest residential properties to the south could have ± 500 persons.

The risk present should a gas leak occur was calculated. These are provided in the report and on aerial photographs. These documents illustrate the extent of the release of effect without mitigation factors. To reduce the impact the gas pipeline on this site is encased. This will reduce the frequency of a release significantly and will also reduce the severity.

The potential severity of a gas leak will vary according to the number of persons on the site and surroundings at te time of the release and if that release ignites. Methane is flammable and this presents the greatest risk.

At this time no end user has been identified.

11.3 Toxic Release

A toxic release will affect all those in the release plume. Inside the release plume fatalities will occur. For Methane the toxic risk is greatest at the source. For most toxic chemicals, a level exists, which if exceeded, death will occur. This level is the Immediately Dangerous to Life and Health Level (IDLH). Methane does not have an IDLH level. At the release source, this limit will occur and it could spread in a pear-shaped plume some distance from the release point. For many substances a level beyond which are safe has been determined. This is known as the toxic end point. The toxic end point for gas (methane) 2900 ppm. The distance to this toxic end point is calculated using one of a number of computer modeling programs.

The behavior of the toxic release is dependent upon many factors. In determining the area of concern and in this area any persons health and life are under threat. All (most) of these factors are accounted for. These parameters are listed in Table 8. These plumes are calculated using:

- ALOHA

12 IMPACT QUANTIFICATION

Event trees establish the size of potential releases and their probabilistic consequence scenarios. The data identifies that most Methane releases results in a toxic release with little to no potential for a fire or an explosion. A scenario from a flammable release that has an impact includes:

- Flash Fires
- Vapour Cloud Explosions

- Pool Fires
- Jet Fires
- Toxic release

Releases of toxic materials can have wide-ranging impacts as toxic clouds.

The severity of impact that can result from these consequence scenarios can be quantified in terms of;

- Heat Radiation for Fireballs, Pool Fires and Jet Fires;
- Explosion Overpressure for Vapour Cloud Explosions;
- Flammable Concentrations for Flash Fires; and
- Toxic load or dose for Toxic clouds 1

For Methane these can occur, however, the toxic load is considered the lowest risk and heat radiation considered the highest.

In order to determine the extent of the impact of the consequence scenarios a model or combination of methods required for each type of consequence. The modeling of the impact of accidental releases of hazardous material extensive subject.

Probit Equations

To quantify the risk of fatality or injury following a hazardous release, a dose response relationship is required, equations are particularly useful for heat radiation or toxic releases, where a sustained low level exposure equally as fatal as an instantaneous high level exposure. Probit equations are usually written in the form:

$$Y = A + B\ln(\text{hazardous load})$$

The probit, Y is a random variable with a mean of 5, and a variance of 1 (for example, Y = 5 corresponds to chance of fatality). Toxic load or dose are interchangeable terms for the integrations over time of the concentration toxic substance, raised to a power termed the dose exponent. The dose exponent has the effect of assigning doses to short exposures at high concentrations than long exposures at lower concentrations.

Toxic load is expressed in terms of concentration (in ppm and/or mg/m^3) with respect to time(s), while thermal radiation terms of intensity (W/m2) and time (s)

toxic load = $\int C\,dt$
thermal load = $(t1^3)/10^4$

Heat Radiation

Explosion Overpressure	Effect
1.2 kW/m2	Received from the sun at noon in summer.
2.1 kW/m2	Minimum to cause pain after 1 minute.
4.7 kW/m2	Will cause pain in 15 - 20 seconds and injury after 30 seconds' exposure.
12.6 kW/m2	Significant chance of fatality for extended exposure. * Thin steel with insulation on the side away from the fire may reach thermal stress level high enough to cause structural failure.
23 kW/m2	* 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.
35 kW/m2	* Cellulosic material will pilot ignite within one minute's exposure. * Significant chance of fatality for people exposed instantaneously.

Table 14: Some Effects of Explosion Overpressure (after HIPAP No 4:1992)

Explosion Overpressure

Explosion Overpressure	Effect
3.5 kPa (0.5 psi)	* 90% glass breakage. * No fatality and very low probability of injury.
7 kPa (1 psi)	* Damage to internal partitions and joinery can be repaired. * Probability of injury is 10 %. No fatality.
14 kPa (2 psi)	* House uninhabitable and badly cracked.
21 kPa (3 psi)	* Reinforced structures distort. * 20 % chance of fatality to a person in a building.
35 kPa (5 psi)	* 50 % chance of fatality for a person in a building and 15 % chance of fatality for a person in the open.
70 kPa (10 psi)	* Threshold for lung damage. * 100 % chance of fatality for a person in a building or in the open. * Complete demolition of house.

Table 15: Some effects of Heat Radiation (after HIPAP No 4:1992)

The greatest risk from pipeline releases identified from previous incidents at other locations and also according to US EPA Statistics (Appendix 9) is a toxic gas release from Pipeline. The sources of these leaks/releases were primary during plant commissioning or during plant maintenance, and the failure to isolate effectively was the main cause of the release.

Research and the assessments of other plants has identified that a number of other potential risks can occur. These are listed below.

Table 16: Incident Outcomes for a gas release from Sasol Pipeline Identified by HAZOP

I	Catastrophic failure/rupture of the pipeline.
II	Small liquid leakage from the pipe - 25 mm release
III	Small liquid leakage from the pipe - 40 mm release
IV	Small liquid leakage from the pipe - 100 mm release

The risk assessment identified and evaluated all information obtained. The elements assessed are provided in Table 17: Major Accidents Scenarios

Table 17: Major Accident Scenarios - Pipeline

Site / Pipeline	**Comment**
Completeness of Hazard Identification Pipeline failure Spill of liquid from pipeline	Full hazard identification not performed. Pipeline underground. This site is an agricultural site and no employees on site. Basic hazard identification performed (site inspection). Adequate information Included as a potential incident source. Included as a potential incident source.
Comprehensiveness of accidents Pipeline leak Catastrophic failure UVCE Rupture of pipeline Puncture of pipeline Leaks on pipeline	No leaks from this pipeline known. All aspects considered, greatest risk is release gas is the flammable toxic risk
Jetflame Flashfire (fireball) Toxic release increasing area of impact	Highest risk flammable. Simple asphyxiant.

In assessing the risk many factors need to be considered or used. These include climatic conditions, topography and surface coverage. To determine uniformity the US EPA, HSE (UK), Dutch and other European countries however, provide a set of input valves. Table 18 lists these factors and the values which need to be applied.

Table 18: Effect of Input Parameters on Predicted Accident Consequences

Parameter	**Accident Type/ Phenomena**	**Acceptable Value**	**Direction to Reduce Severity of Consequences**
Wind speed	Passive dispersion	2 m/s F stability 5 m/s D stability	± ±
	Vertical jet	10 - 15 m/s towards the target and 5 m/s	±
	Horizontal jet	0 - 5 m/s with and against the jet	±
Ground roughness	Dense gas and jet dispersion	0.3 k (suburban environment)	±
Averaging period	Dispersion of gas cloud	600s plume 10s puff	± ±
Elevation of fireball	Pressure vessel rupture	touching the ground	±
Humidity	Fireball and jet fire	60% or less	±
Surface emissive power	Fireball	270 kW/m²	±
	Jet fire	200 kW/m² or 0.3 of heat of combustion	±
	Pool fire	200 kW/m² over half of the flame height	±
Stored energy in Vapour cloud	VCE	3.5x10 J/m³	±
Substrate	Vaporising pool	substrate heat capacity (on concrete or tarmac)	±

"The harm criteria or vulnerability models used to assess the impact of each MAH on people and the environment should be appropriate and have been used correctly for each relevant major accident." HSE

Where the risk is an explosion or fire the safety report should calculate thermal radiation and explosion over pressure hazard ranges and casualties for several levels. The undermentioned should be for thermal radiation.

1 Dangerous dose of thermal radiation for vulnerable people (500 tdu); equivalent to 4.9 kw/m² exposure for 1 minute.

2 Dangerous dose of thermal radiation for average members of society (1000 tdu); equivalent to 8.2 kW/m² exposure for 1 minute.

3 Significant likelihood of death (1800 tdu); equivalent to 12.8 kW/m² exposure for 1 minute.

For over pressure, the appropriate hazard ranges corresponds to:

4 Window breakage (40 mbar);

5 Houses uninhabitable but repairable (100 mbar);

6 Severely damaged houses (200 mbar);

7 Houses completely demolished (500 mbar).

Methane is considered primarily as a flammable health risk. Methane is also toxic risk.

12.1 Impact Quantification at Sasol Gas Pipeline

The pipeline operates 24 hours per day, 365 days per year and the pipeline has been located on this site for more than 20 years. According to Sasol records no significant releases of gas have occurred in the last 5 years.

The risk assessment obtained data and evaluated this data to determine the risk.

The factors listed in Table 13 were considered and evaluated. These are discussed below.

12.1.1 Off Site Events

Events which originate off site and can impact on the site causing a significant event.

12.1.1.1 Aircraft impact

The nearest international airport (King Shaka International Airport) is located less than 10 km from this site. The MHI risk criteria for inclusion of an aircraft impact also required if the airport is within 16 km of this site this has further been reduced to 10 km. Therefore the risk of impact from an aircraft was considered.

12.1.1.2 Subsidence

This site is flat. This was not a significant factor, however ground movement has been established as one of the highest risk factors and one to cause a potential severe consequence. Sasol has designed the pipeline to reduce this potential risk. Any work by the developer on this site will comply with Sasol standards. These are attached. At present this is a low risk.

Historically data from EGIG, USA DoT and others has identified this as a potential to cause significant effects. Based on this a document IGEM/TD/2 was developed and should be used.

Table 18: Failure Rate due to Landslide from Different Slope Types

Description	**Pipeline Rupture Rate (per km-year)**
Slope instability is negligible or unlikely to occur, but may be affected by slope movement on adjacent areas	0 to 9 E-5
Slope instability may have occurred in the past or may occur in future - is present and may occur in the future	1 E-4 to 2.14 E-4
Slope instability is likely and site specific assessment is required	>3 E-4

The potential for subsidence or landslide to occur is very low.

12.1.1.3 Extreme Environmental Conditions

Most conditions do not present a significant risk. This site can be flooded, steam is located nearby. EGIG data identified that lightning is a potential threat. The EGIG data of incidents identified 57% of the incidents with ignition was from lightning as the source. Lightning is one potential risk.

12.1.1.4 Vehicle Impact

The pipeline is underground. The developer will not work in the Sasol gas pipeline servitude. No vehicle can damage the pipeline.

12.1.1.5 Explosions

This can occur and is a potential risk. For this to occur a gas leak would need to ignite and then explode. Sabotage/arson can be a cause. The mitigational measures of the pipeline being underground reduces this risk significantly.

12.1.1.6 Fire

If a gas release occurs, it can ignite. The potential for ignition will be dependent upon the amount of gas released. Below its lower flammable limit ignition is limited and above the Upper Flammable limit it is also limited. Fires occurring at a gas release at a pipeline, based on statistical information/references is about 4% for the gas releases igniting.

12.1.1.7 Missiles

Limited risk.

12.1.1.8 Pipeline rupture

This can occur. The potential failure of the pipe is considered in this report. EGIG identifies that full bore (rupture) pipeline can occur. The EGIG and UK data indicates no full bore ruptures has occurred from 1984 to date. This does not mean that such an occurrence will not happen. Based on our 25 years of data the frequency of a full bore rupture can be 1 x 10^{-7} per year. Furthermore if the pipeline wall thickness was also considered then the failure rate of materials could be further reduced to 5.8 x 10^{-5} per year.

EGIG does identify that a gas release from a larger pipeline has a greater potential to ignite.

Table 19: Ignition probability per size of leak

Size of leak	Ignition Probability (%)
Pinhole - crack	4
Hole	2
Rupture	13

Table 20: Ignition probability for rupture to ignite

Size of leak	Ignition Probability (%)
Rupture <16 inches	10
Rupture >16 inches	33

Sasol has introduced mitigation measures to reduce the risk. The risk appears to be low.

12.1.2 Operator Error

The pipeline is underground. No work on the pipeline by the developer and/or the tenant or new landlord or user will occur. The developer will comply with Sasols standards to reduce the risk. The measures implemented are provided in the Appendices.

Sasol maintains its pipeline. This will continue.

12.1.3 Abnormal Load

The pipeline is underground. The pipeline has a servitude. No work in the servitude or around the pressure reducing pump station will occur.

This will prevent any load on the pipeline. The risk is therefore very low.

12.1.4 Arson and/or Sabotage

This was identified as a potential high risk. Dissatisfied persons could attempt to sabotage the pipeline. This can cause an environmental pollution problem. This person(s) could also ignite the gas or cause an explosion.

The developer will ensure access control. This should reduce the potential.

To reduce this risk management must ensure that site access is controlled/maintained and that education of employees to reduce dissatisfaction and to explain the potential consequences.

12.1.5 Inadequate Management

On site, the owners and tenants on this site will not manage or be involved in the pipeline however, they will be responsible for their employees, contractors on site and the general public. The owner/body corporate/manager and each of the tenants will be required to draw up and provide emergency plan for all persons on site or on these sites and will need to practice and evacuation at least once per year. Sasol will continue to manage the pipeline.

12.1.6 Loss of Service

The site services (electricity, water, etc) has no involvement with or bearing on the pipeline and therefore it will not influence the pipeline and/or its activities.

DATA SOURCES AND ASSUMPTIONS

The potential risk and equipment failure rate data sources are listed below in descending order of preference:

These failure rates are from a variety of published data for chemical plants **(References 34, 35, 38, 39 and 41)**, and from generic published data for mechanical equipment **(Reference 39, 41 and 42)**.

To determine the potential for equipment failure or other failure which can cause a major incident. The assessment includes professional judgment.

Professional judgment

Where it is required to quantify human error probabilities, References 34, 35, 38, 39 and 41 is used as the source reference. The human error probabilities used are standard for the process industries. The method for determining the frequency of aircraft crashes was taken from **HSE (ref 42).**

Reference 34, 35, 38, 39, 41 and 42 contain failure rate data from a number of sources, mainly from the chemical and petro-chemical industries, and synthesize the data to arrive at expected frequencies of losses of containment for various items of equipment.

Where no referenceable data is available, Professional judgment is used.

Table 21: Notes & Assumptions Used to Determine Event Frequencies

Note	Description	Reference
1	The background aircraft crash rate is made up of two components; the overall background crash rate plus the airfield rate determined by the location of local airfields and aircraft movements from these fields. Airfields only need to be considered if they are within 16 km of the location of interest. This site is within the specified range. Reference 42 gives the background crash rate for aircraft in the UK as 6.1×10^{-5} per km^2 per year.	**HSE**
2	Pipeline release of gas. (1×10^{-6})	**Professional Judgment**
3	Pipeline release of gas and it ignites (3.0×10^{-7})	**Professional Judgment**

12.2 Initiating Event Frequency Assessment

12.2.1 *Catastrophic Failure*

The following table details the events, which have been identified in Hazard Register that would result in the catastrophic failure of the gas pipeline.

Table 22: Catastrophic Failure

Failure Mode	**Base Event**		**Frequency (yr^{-1})**	**Notes**
	Frequency	**Source**		
Aircraft Impact	0.54×10^{-9} /yr	HSE	0.54×10^{-9} /yr	1
Pipeline gas release	1.0×10^{-6} /yr	Professional Judgment	1.0×10^{-6} /yr	2
Pipeline gas release ignites	3.0×10^{-7} /yr	Professional Judgment	3.0×10^{-7} /yr	2
		Subtotal	1.31×10^{-6}	

13 ESTIMATION OF FREQUENCIES AND CONSEQUENCES

The accident scenarios for pipeline installations are shown below and their associated frequency of occurrence. These are based on EPA and HSE and were used to calculate the risk contours.

Table 23: Some risks of death expressed in annual experiences in the UK

Cause	Risk as an annual experience	Risk (cpm)
All causes	1 in 87	11490
Road accidents	1 in 10 294	98
Harmful gas incidents	1 in 1 510 000	0.66

The Risk Assessment is based on the UK HSE and US EPA methods and methodologies. The scenarios and frequencies chosen are generic set of scenarios EPA ALOHA AND EPA RMP Comp were used to determine the potential risk and areas of concern.

The individual risk contour lines of 10, 1 and 0.3 chances per million per year of receiving a dangerous dose were calculated and are illustrated on the aerial photo. The 10, 1 and 0.3 cpm values are the risk levels used by the HSE to set the three (3) zone land use planning policy.

The individual risk contours indicate a low and acceptable public risk level as the contours where the release can go does not reach any residential or vulnerable area. The risk assessment identifies that the 10 cpm is restricted to the site.

For the exposed population (general public) as a whole, the HSE uses the upper bound for risk of a dangerous dose or worse as 10^{-5}/year (10 cpm) and as the lower bound 10^{-6}/year (1cpm). For this site the lower limit does not occur (1 x 10-5 per year) and the general public will vary.

For cases where the exposed population contains a high proportion of vulnerable people (ages, babies, young child) the lower bound is 0.33×10^{-6} per year (0.33). The HSE broadly acceptable risk is 1 x 10^{-6} per year (1 cpm). This does not apply as the area of concern does not reach any public road, residential property and/or school.

The cases of pipeline releases are listed in the Appendices (Appendix 9). Fatalities have occurred during some of these incidents. Using the table Incident Outcomes for pipelines, these consequences of such an event was determined.

Table 24: Consequence Analysis of Incident Outcome for various Atmospheric Stability Classes

Incident Outcome	t/min	Toxic Dispersion amount released	Area of concern m	Frequency of incident outcome
I	160 minutes	1289920 kg	190 m	1 x 10^{-5}

In the areas of concern, low occupancy occurs and those at risk are site employees and contractors. Where the gas can escape the boundary fence the area is not habititated.

PAC-1: 2 900 ppm
PAC-2: 2 900 ppm
PAC-3: 17 000 ppm

14 SOCIETAL RISK

Societal risk measures the risk to a group to people not involved in the plant (CCPS 1989).

The Societal risks (as used by the UK HSE) should meet the criteria in R2P2, that is likelihood of a single major industrial activity producing 50 or more fatalities should be less than 1 in 5 000 (less than 2 x 10^{-4} per year).

Societal risk measures estimate both the potential size and likelihood of incidents with multiple adverse conditions. The assessment of this risk is important for managing risk in situations where there is a potential for accidents, injuries and or fatalities.

The common measure of this is the F.N. Curve.

These frequency - Number (F.N. curve) begin is to calculate the number of fatalities resulting from each incident outcome case.

Societal risk is dependent on the population distribution (general public, employees) normally around the site as well as their location (indoors vs outdoors).

$$Ni = \sum_{x, y} P_{x, y} P_f$$

The number of people is obtained from those in the impact zone (area of concern). Prior to implementation of control measures by an Individual and Societal Risk occurred. The controls implemented have reduced the risk and this risk is only at the pipeline. Therefore no Individual Risk and no Societal Risk occurs.

The developer does not propose to implement mitigational measures unless recommended by the pipeline owner (Sasol) or from the findings of this risk assessment.

The Sasol pipeline location on this site is provided in Appendix 4. The area where the pipeline is located is to be used as a green belt and limited activity will occur in this area. At some locations minor works in the form of road crossings, driveways and open parking areas are situated on or over the servitude.

Societal risks are calculated using individual risks to determine the number of fatalities in the area of impact, the potential location of the people indoors/outdoors, ignition probabilities and when it could occur (day or night).

Table 25: Number of potential fatalities due to the toxic/flammable release without mitigation

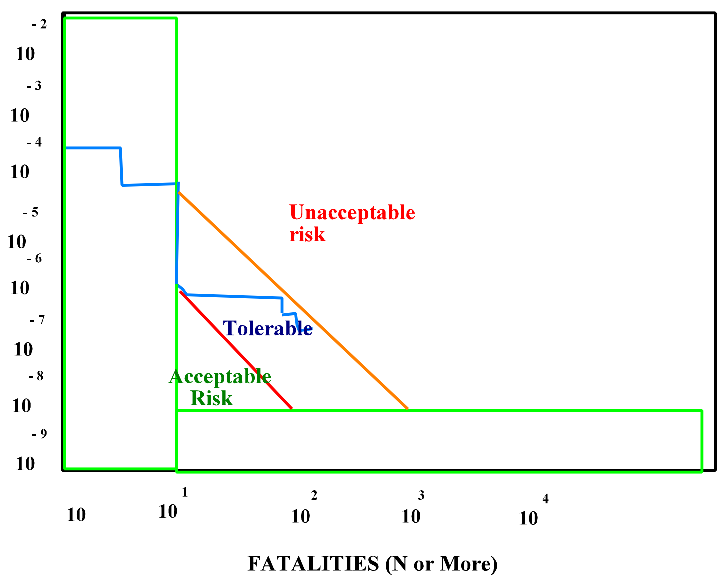
Wind direction	Incident frequency/per year	Affected area	Offsite	Number of people at risk	
				Affect site	Offsite
N	2.0×10^{-7}	Yes	Yes	Unknown, will vary	Unknown, few due to terrain
NE	2.0×10^{-7}	Yes	Yes. Restricted due to terrain	Will vary	Unknown, few due to terrain
E	2.0×10^{-7}	Yes	Yes. Restricted due to terrain	Will vary	Unknown, few due to terrain
SE	2.0×10^{-7}	Yes	Yes	Will vary	Unknown. Most areas not developed
S	2.0×10^{-7}	Yes	Yes	Will vary	Unknown. Most areas not developed
SW	2.0×10^{-7}	Yes	Yes	Will vary	Unknown
W	2.0×10^{-7}	Yes	Yes	Will vary	Unknown
NW	2.0×10^{-7}	Yes	Yes	Will vary	Unknown, restricted due to terrain

With the mitigation implemented the risk has been reduced and the risk of a gas risk on site is low and will be contained underground. No risk to individuals or to the general public (persons other than employees) now occurs.

No societal or individual risks were determined as no person is at present in the areas of concern on this site and that the areas of concern do not impact on offsite surrounding communities. Once the developers determine the user or users these can be calculated.

Figure 4:

F-N CURVE



15 SUMMARY OF RISK

15.1 Risk summary

Exposure to Methane can present a significant health hazard.

This assessment identified that the release of Methane, from the Sasol gas pipeline would present a health risk for all persons within a 190 m radius from the release point under worst case conditions without mitigational measures. Due to the terrain and climatic conditions, the area of effect could be larger than that calculated. The details of the health effects are provided in the Appendix 5.

The Risk Assessment identified the following:

- The greatest risk would be a gas release which ignites. This would be a worst case release. This release would be rare and in general is low in probability. The developer has encased the pipeline. This has reduced the risk to very low and contained at the pipeline.

- The release of Methane from a leak could affect an area of 190 m around the source. The implementation of the enclosure has reduced this area to the area of the pipeline.

- Sasol are responsible for any maintenance.

This mitigation measure is considered to be the best method of preventing pipelines presenting a significant risk. The mitigational measures implemented identify that the site should be declared an MHI and that once the decision as to the type of development has occurred its suitability needs to be determined. The HSE UK criteria for land use planning (PADHI) is used for this.

To determine the suitability of the development the UK criteria for land planning PADHI should be used. The table below provides the guidance. PADHI uses the inner, middle and outer zones to determine the suitability of the development.

All three zones inner, middle and outer are located at and around the pipeline and its servitude. The outer zone is 132 m around the pipeline.

Table 26: PADHI Planning

Level of sensibility	Development in inner zone	Development in middle zone	Development in outer zone
1	DAA	DAA	DAA
2	AA	AA	AA
3	AA	AA	AA
4	AA	AA	AA

DAA = Don’t Advise Against Development
AA = Advise against Development

Level of suitability:

1. Based on normal working population (less sensitive)
2. Based on general public at home

3. Based on vulnerable people
4. Based on larger developments in Category 2 and 3

Guidelines as to the development or potential development are provided in Appendix 10. The Developer must ensure the following:

15.1.1 Liaise with Sasol Gas prior to any development. Determine the type of development and its suitability.

15.1.2 Maintain existing measures implement (no building or work in pipeline servitude) and maintain this area.

15.1.3 Ensure that fire prevention controls are implemented on this site and that these meet the LA Fire Bylaws.

15.1.4 Provide a Control Centre for emergencies.

15.1.5 Educate all employees, contractors and tenants of health risks of exposure to Methane gas, the emergency plan and their role, should an emergency occur.

15.1.6 Continue to restrict access to the site.

15.1.7 Develop an Emergency and Crisis Management plan for the facilitate. Once developed, this must be tested, practised regularly (at least once per year).

16 CONCLUSION

The Sasol gas pipeline was designed according to specifications at the time and this would have been adequate at that time. The pipeline is operated and maintained according to recognised and prescribed procedures. Sasol employees are trained and there is reasonable supervision, control and auditing. The developer must liaise with Sasol and determine or accept mitigational measures to limit the risk to the general public. Developers and their tenants still however need to implement an Emergency Plan. The purpose of this Emergency plan should be:

1. Preventing accidental chemical releases which could be toxic, explosive or flammable.
2. Reducing risk to community.
3. Minimising the consequences of releases on the environment.
4. Enable management to respond to an emergency efficiently and effectively and to reduce a risk.

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MAJOR HAZARDOUS INSTALLATION

Risk Model
Risk Summary

REF.	EVENT	RESULT	REDUCTION	RATING			DECISION
				SEVERITY	FREQUENCY	REDUCTION	
1.	Failure of pipeline localised failure.	Release of Methane into atmosphere.	1. Odour can be detected easy. 2. Maintenance program - Sasol 3. Inspection program - Sasol 4. Emergency response - Sasol 5. Training - all employees trained. 6. Emergency plan - required 7. Access control and only authorized persons	1	1	1-9	
1.1.		Release of Methane into atmosphere. Formation of gas/vapour cloud in area.	1. Odour can be detected easy. 2. Maintenance program. 3. Inspection program. 4. Emergency response. 5. Training - all employees trained. 6. Emergency plan 7. Access control and only authorized persons 8. Crisis Management plan required.	2	1	1-10	
1.2		Release of Methane into atmosphere. No initial ignition, formation of gas/vapour cloud, and this blows towards Warehouse and other offsite properties No ignition of cloud - Toxic levels.	1. Odour can be detected easy. 2. Maintenance program. 3. Inspection program. 4. Emergency response. 5. Training - all employees trained. 6. Emergency plan 7. Access control and only authorized persons 8. Area locked and only authorised personnel allowed. 9. Crisis Management plan required.	4	1	1-11	

REF.	EVENT	RESULT	REDUCTION	RATING			DECISION
				SEVERITY	FREQUENCY	REDUCTION	
2	Release of Methane from pipeline Worse Case	Release of toxic vapour cloud. Release of gas for at least 120 minutes (Sasol requires this period to stop a release).	1. Odour can be detected easy. 2. Maintenance program. 3. Inspection program. 4. Emergency response. 5. Evacuation plans. 6. Training 7. Access control and only authorized persons 8. Crisis Management plan required			1-9	
2.1		Release of Methane vapours	1. Odour can be detected easy. 2. Maintenance program. 3. Inspection program. 4. Emergency response BA available. 5. Evacuation plans. 6. Training 7. Access control and only authorized persons 8. Crisis Management plan required 9. Alert Sasol and LA Fire Brigade/Emergency Services.	2	2	1-9	
2.2		Released into atmosphere and surrounding area Methane cloud toxic level will exceed boundary. Could affect 50 - 500 m around site.	1. Odour can be detected easy. 2. Maintenance program. 3. Inspection program. 4. Emergency response BA available. 5. Evacuation plans. 6. Training 7. Access control and only authorized persons 8. Crisis Management plan required 9. Alert Sasol and LA Fire Brigade/Emergency Services.	5	1	1-9	
2.3		Release and ignition occurs. Risk restricted to area around tank. But if explosion, flying objects will be a danger.	1. Employees trained. 2. Signage 3. Fire fighting equipment available. Employees trained. 4. Emergency plan. 5. Emergency response.	2 - 5	1	5	

REF.	EVENT	RESULT	REDUCTION	RATING			DECISION
				SEVERITY	FREQUENCY	REDUCTION	
3	Natural disaster. Storm, Equipment damaged. Pipe connections and valves damaged.	Release of Methane into atmosphere. No initial ignition, formulation of vapour cloud. Vapour cloud forms in area also infiltrates plant and drainage channels, and community.	1. Natural wind dispersion. 2. Manually shut off valves if possible. 3. Fire fighting response - Employees trained. 4. Emergency response. 5. Evacuation and Emergency plan. 6. Crisis plan required. 7. Emergency services Sasol Risk and Emergency Services and LA notified. 8. Can be diluted by wind.	5	1	1-8	
4	Sabotage. Deliberate release and/or ignition of gas.	One or more of the above scenarios.	Applicable response as above.	5	1	1-8	

Rating Categories

SEVERITY		FREQUENCY		REDUCTION		COMMENTS
Slight injury and/or damage	**1**	Once in 10 years or less	**1**	Routine procedures	**1**	
Serious injury and/or damage	**2**	Once per year	**2**	Annual procedures	**2**	
Certain death & major damage	**3**	Once per Quarter (3 months)	**3**	Quarterly procedures	**3**	
Injury and/or damage outside site	**4**	Once per month	**4**	Monthly routines	**4**	
Catastrophe, multiple deaths and major damage	**5**	Frequently	**5**	Immediate action	**5**	
			6	Design parameters		
			7	Emergency procedures and plans		
			8	Procedures controls		

RISK ANALYSIS - MAJOR HAZARD INSTALLATION

Pipeline Release - Sasol
(Methane Gas)

ISSUE	POTENTIAL THREAT	CONSEQUENCE OF THREAT MATERIALISING	SIGNIFICANCE OF CONSEQUENCE	EFFECTS	CONSEQUENCE (SEVERITY)	PROBABILITY OF OCCURRENCE	RISK RATING	
							BEFORE ACTION	AFTER ACTION
Release of Methane and the Methane or its vapour does not ignite.	1. Fire/explosion 2. Potential health threat 3. Release through fire/explosion	1. Presents health/safety risk 2. Fire/explosion 3. Damage to plant	1. Injury 2. Damage 3. Damage equipment and plant 4. Potential explosion 5. Potential health safety environmental risk	1. Safety risk 2. Health risk 3. Environmental Community Issue. 4. Damage 5. Fire/explosion	Damage is dependent upon the amount released.	Normal operations - low risks Accident/incidents risk increases can happen	LOW HIGH	

ISSUE	POTENTIAL THREAT	CONSEQUENCE OF THREAT MATERIALISING	SIGNIFICANCE OF CONSEQUENCE	EFFECTS	CONSEQUENCE (SEVERITY)	PROBABILITY OF OCCURRENCE	RISK RATING	
							BEFORE ACTION	AFTER ACTION
Release of Methane and Methane and/or its vapour ignites and explosion occurs	1. Fire/explosion 2. Potential health threat 3. Release through fire/explosion	1. Presents health/safety risk 2. Fire/explosion 3. Damage to plant	1. Injury 2. Damage 3. Damage equipment and plant 4. Potential explosion 5. Potential health safety environmental risk	1. Safety risk 2. Health risk 3. Environmental Community Issue. 4. Damage 5. Fire/explosion	Damage is dependent upon explosion. Flying objects can affect an area of 200 - 300 m.	Normal operations - low risks Accident/incidents risk increases can happen	LOW HIGH	

ISSUE	POTENTIAL THREAT	CONSEQUENCE OF THREAT MATERIALISING	SIGNIFICANCE OF CONSEQUENCE	EFFECTS	CONSEQUENCE (SEVERITY)	PROBABILITY OF OCCURRENCE	RISK RATING	
							BEFORE ACTION	AFTER ACTION
Toxic release no ignition and/or explosion	Potential health threat - employees - Sasol - general public/other companies employees.	1. Presents health/safety risk	1. Injury 2. Damage 3. Potential health safety environmental risk	1. Safety risk 2. Health risk	Employees can be affected. Consequences can be severe - death - irreversible damage - unconscious - lung damage	Low risk - normal operations Incident can occur and risk increase	LOW Emergency Risk HIGH	

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Appendices