PROJECT DONE ON BEHALF OF
SAVANNAH ENVIRONMENTAL (PTY) LTD

QUANTITATIVE RISK ASSESSMENT OF THE PROPOSED PRBGP3 AT RICHARDS BAY, KWAZULU NATAL

Author: M P Oberholzer
Date of Issue: 2nd of August 2022
Report No.: 22SAV-01 Rev 2

RISCOM®

P O Box 2541, Cresta, 2118
Tel: +27 (0) 11 431 2198
Cell: +27 (0) 82 457 3258
Fax: +27 (0) 86 624 9423
Email: mike@riscom.co.za

DOCUMENT CHANGE HISTORY			
PAGE / LINE	**CHANGE**	**DATE**	**REV**
Document	Initial release	6 May 2022	0
Document	Updated with client's comments	7 May 2022	1
5-6 / Fig 5-3	Updated to ammonia	2 August 2022	2
7-7 / 42	Added a paragraph	2 August 2022	2

RISCOM (PTY) LTD

RISCOM (PTY) LTD is a consulting company that specialises in process safety. Further to this, RISCOM[1] is an approved inspection authority (AIA) for conducting Major Hazard Installation (MHI) risk assessments in accordance with the OHS Act 85 of 1993 and its Major Hazard Installation regulations (July 2001). In order to maintain the status of approved inspection authority, RISCOM is accredited by the South African National Accreditation System (SANAS) in accordance with the IEC/ISO 17020:2012 standard. The accreditation consists of a number of elements, including technical competence and third-party independence.

The independence of RISCOM is demonstrated by the following:

- RISCOM does not sell or repair equipment that can be used in the process industry;
- RISCOM does not have any shareholding in processing companies nor companies performing risk assessment functions;
- RISCOM does not design equipment or processes.

Mike Oberholzer is a professional engineer, holds a Bachelor of Science in Chemical Engineering and is an approved signatory for MHI risk assessments, thereby meeting the competency requirements of SANAS for assessment of the risks of hazardous components, including fires, explosions and toxic releases.

M P Oberholzer Pr. Eng. BSc (Chem. Eng.) MIChemE MSAIChE

* RISCOM™ and the RISCOM logo are trademarks of RISCOM (PTY) LTD

QUANTITATIVE RISK ASSESSMENT OF THE PROPOSED PRBGP3 AT RICHARDS BAY, KWAZULU NATAL

EXECUTIVE SUMMARY

1 INTRODUCTION

Phakwe Richards Bay Gas Power 3 (Pty Ltd) proposes to operate a combined cycle gas power plant (hereinafter referred to as PRBGP3) of up to 2000 MW nominal capacity that will operate on natural gas (in either liquid or gas forms) or a mixture of natural gas and hydrogen (in a proportion scaling up from 30% hydrogen - H_2) which will be transported to the site via a pipeline.

The Project site is to be located Municipally within the Richards Bay Industrial Development Zone 1F (RBIDZ 1F), situated North of the Richards Bay centre, which falls within the jurisdiction of the City of uMhlathuze Local Municipality and the King Cetshwayo District Municipality in the KwaZulu-Natal Province.

Since off-site incidents may result due to hazards of some of the chemical components to be stored on, produced at or delivered to site, RISCOM (PTY) LTD was commissioned to conduct a quantitative risk assessment (QRA), the impacts onto surrounding properties and communities as part of an environmental impact assessment (EIA).

1.1 Terms of Reference

The main aim of the investigation was to quantify the risks to employees, neighbours and the public with regard to the proposed PRBGP3 facility at Richards Bay.

This risk assessment was conducted in accordance with the MHI regulations and can be used as notification for the facility. The scope of the risk assessment included:

1. Development of accidental spill and fire scenarios for the facility;
2. Using generic failure rate data (for tanks, pumps, valves, flanges, pipework, gantry, couplings and so forth), determination of the probability of each accident scenario;
3. For each incident developed in Step 2, determination of consequences (such as thermal radiation, domino effects, toxic-cloud formation and so forth);
4. For scenarios with off-site consequences (greater than 1% fatality off-site), calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality.

1.2 Purpose and Main Activities

The main activity of the proposed PRBGP3 facility in Richards Bay would be the generation of mid-merit power supply to the South African electricity grid. The fuel used to generate power would be LPG, that will be delivered to site by truck.

1.3 Main Hazards Due to Substance and Process

The main hazards that would occur with a loss of containment of hazardous components at the proposed PRBGP3 facility in Richards Bay include exposure to:

- Thermal radiation from fires;
- Overpressure from explosions.

2 ENVIRONMENT

The site location for the proposed PRBGP3 facility is on 16820, 16819,1/16674 and a subdivision of erf 17442 within the Richards Bay IDZ Zone 1F, and will occupy approximately 11.8 ha, as shown in Figure 2-1.

The white lines indicated the boundary of the RBIDZ 1F, with the entrance located to the east.

RBGP3 in Richards Bay is approximately 8 km from the deep-sea port.

Figure 2-1: Proposed PRBGP3 location within the RBIDZ 1F

The RBIDZ 1F is an industrial zoned park that has an access control point, whereby all traffic and people are controlled. Thus, all people entering the site will be limited to workers, and the general public will not have access to free movement within the zoned area.

The land use surrounding the proposed PRBGP3 facility is shown in Figure 2-1.

The closest residential area is Wild En Wiede lying approximately 2.5 km from the proposed PRBGP3 facility.

3 PROCESS DESCRIPTION

3.1 Site

The proposed PRBGP3 facility in Richards Bay is to consist offices, workshops, gas and steam turbines and associated equipment, as shown in Figure 3-1.

The site will be accessed via the main entrance of the RBIDZ 1F. Thus, all unauthorised people and the general public will be excluded from the RBIDZ 1F.

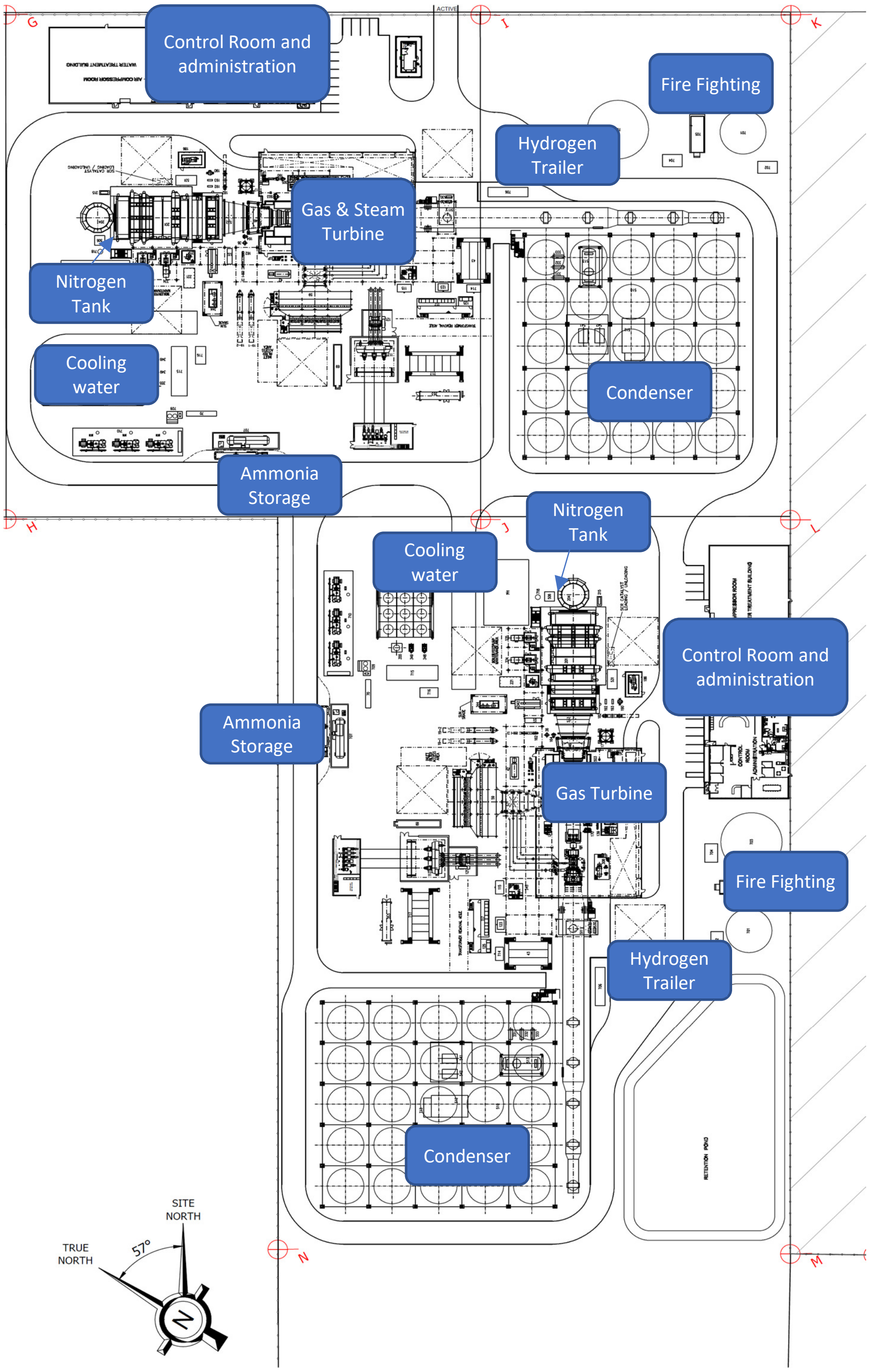


Figure 3-1: Site layout

3.2 Process Description

The project will consist of up to 4 closed cycle gas turbines (CCGT) used to produce a nominal capacity of 2000 MW power from natural gas (in either liquid or gas forms), or a mixture of natural gas and hydrogen (in a proportion scaling up from 30% hydrogen - H2) as a fuel.

The process for converting the energy in a fuel into the electric power involves the creation of mechanical work, which is then transformed into the electric power by a generator. The overall efficiency of the conversion depending on the type of fuel and the thermodynamics process used and it can be as low as 30%.

To increase the overall efficiency of electric power plants, multiple thermodynamic processes can be introduced or combined to recover and utilize the residual heat energy in hot exhaust gases. By the use of combined cycle, power plants can achieve the electrical efficiency up to 60%.

The terms "combined cycle" refers to the combining of multiple thermodynamic cycles to generate electric power. Combined cycle operation uses a heat recovery steam generator (HRSG) that captures the heat from high temperature exhaust gases to produce steam, which is then supplied to a steam turbine to generate additional electric power. The process for creating steam to produce work using a steam turbine is based on the Rankine cycle.

The most common type of combined cycle power plant utilizes gas turbines and is called a combined cycle gas turbine (CCGT) plant. Because gas turbines have low efficiency in simple cycle operation and the output produced by the steam turbine accounts for about half of the CCGT plant output.

The simplified schematic of the (CCGT) power plant is shown in Figure 3-2, and consists of the following steps that are carried out in combined-cycle plants to produce electricity, including the capturing of the wastage heat from the gas turbine to increase efficiency and electrical output.

1. Gas turbine burns fuel (gas):
   - The gas turbine compressed the air and mixed it with fuel that is heated to a very high temperature. Then the hot air-fuel mixture moves through the gas turbine blades, making them spin.
   - The fast-spinning of turbine drives a generator that converts a portion of the spinning energy into electricity.
2. Heat recovery system captures exhaust (HRSG):
   - A Heat Recovery Steam Generator (HRSG) captures the exhaust heat energy from the gas turbine that would otherwise escape through the exhaust stack / chimney.
   - The HRSG helps to creates steam from the gas turbine exhaust heat and it delivers to the steam turbine.
3. Steam turbine delivers additional electricity:
   - The steam turbine sends its energy to the generator drive shaft, where it is converted into additional electricity.

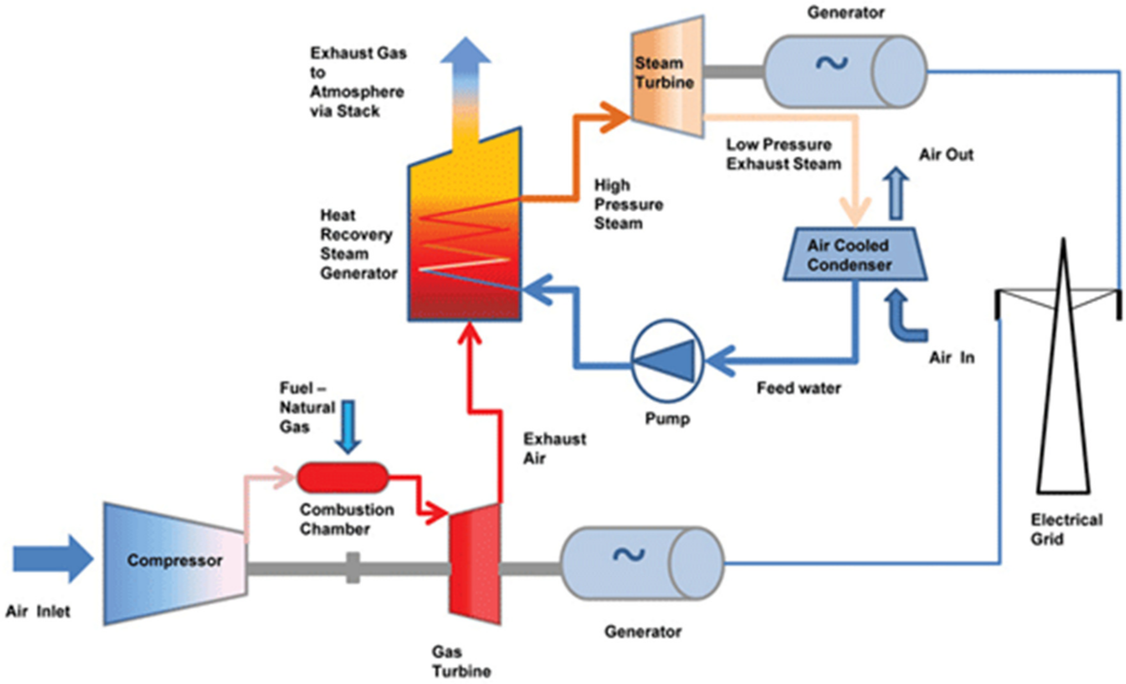


Figure 3-2: Simplified schematic of a CCGT power plant

3.3 Fuel and Process Chemicals

3.3.1 Natural Gas

Natural gas would be used to fuel the gas turbines. The gas will be supplied via a pipeline at an estimated flow rate of 5570 Nm^3/hr per gas turbine. This study assumes a gas supply pressure of 60 bar and 1ºC - 10ºC. No storage of natural gas would be provided.

3.3.2 Diesel

An 80 m^3 diesel storage tank would be provided for emergency power. At this stage of the design, the diesel storage tank location is unknown.

3.3.3 Hydrogen

One hydrogen trailer per gas turbine has been provided in the design. The trailer is assured to be that of a standard hydrogen trailer of 190 kg hydrogen inventory with a storage pressure at 225 bar(g).

3.3.4 Ammonia

Ammonia would be used to adjust the pH of the boiler water feed. The size and storage details of the ammonia has not been provided. However, the ammonia tank dimensions measured from the layout provided a 60 m^3 ammonia tank per gas turbine.

3.3.5 Nitrogen

Nitrogen would be required to purge natural gas in pipelines and equipment prior to conducting maintenance.

The nitrogen designs have not been specified at this stage of the project. This study assumes a single 30 m^3 cryogenic storage tank will be used.

4 METHODOLOGY

The first step in any risk assessment is to identify all hazards. The merit of including a hazard for further investigation is then determined by how significant it is, normally by using a cut-off or threshold value.

Once a hazard has been identified, it is necessary to assess it in terms of the risk it presents to the employees and the neighbouring community. In principle, both probability and consequence should be considered, but there are occasions where, if either the probability or the consequence can be shown to be sufficiently low or sufficiently high, decisions can be made based on just one factor.

During the hazard identification component of the report, the following considerations are taken into account:

- Chemical identities;
- Location of on-site installations that use, produce, process, transport or store hazardous components;
- Type and design of containers, vessels or pipelines;
- Quantity of material that could be involved in an airborne release;
- Nature of the hazard most likely to accompany hazardous materials spills or releases, e.g., airborne toxic vapours or mists, fires or explosions, large quantities to be stored and certain handling conditions of processed components.

The evaluation methodology assumes that the facility will perform as designed in the absence of unintended events such as component and material failures of equipment, human errors, external events and process unknowns.

SANS 1461 (2018) is based on RIVM (2009) for process plants. The latter standards describe the minimum scenarios to be included in the assessment, as well as the assumptions to be used. As full compliance of SANS 1461 (2018) cannot be achieved within the NEMA legislative framework, general compliance of the aforementioned standards at this stage would be applicable and briefly described in the sections below. This general compliance assessment constitutes a quantitative risk assessment (QRA).

The QRA process is summarised with the following steps:

1. Identification of components that are flammable, toxic, reactive or corrosive and that have potential to result in a major incident from fires, explosions or toxic releases;
2. Development of accidental loss of containment (LOC) scenarios for equipment containing hazardous components (including release rate, location and orientation of release);
3. For each incident developed in Step 2, determination of consequences (such as thermal radiation, domino effects, toxic-cloud formation and so forth);
4. For scenarios with off-site consequences (greater than 1% fatality off-site), calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality.

5 CONCLUSIONS

Risk calculations are not precise. Accuracy of predictions is determined by the quality of base data and expert judgements.

This risk assessment included the consequences of fires and explosions at the proposed PRBGP3 facility in Richards Bay. A number of well-known sources of incident data were consulted and applied to determine the likelihood of an incident to occur.

This risk assessment was performed with the assumption that the site would be maintained to an acceptable level and that all statutory regulations would be applied. It was also assumed that the detailed engineering designs would be done by competent people, and would be correctly specified for the intended duty. For example, it was assumed that tank wall thicknesses have been correctly calculated, that vents have been sized for emergency conditions, that instrumentation and electrical components comply with the specified electrical area classification, that material of construction is compatible with the products, etc.

It is the responsibility of the owners and their contractors to ensure that all engineering designs would have been completed by competent persons, and that all pieces of equipment would have been installed correctly. All designs should be in full compliance with (but not limited to) the Occupational Health and Safety Act 85 of 1993 and its regulations, the National Buildings Regulations and the Buildings Standards Act 107 of 1977 as well as local bylaws.

A number of incident scenarios were simulated, taking into account the prevailing meteorological conditions, and described in the report.

5.1 Notifiable Substances

The General Machinery Regulation 8 and its Schedule A on notifiable substances, requires any employer who has a substance equal to or exceeding the quantity listed in the regulation to notify the divisional director. A site is classified as a Major Hazard Installation if it contains one or more notifiable substances, or if the off-site risk is sufficiently high. The latter can only be determined from a quantitative risk assessment.

The notifiable threshold for ammonia is listed 20 t in a single vessel. As the proposed installation exceeds the threshold limit, ammonia will be classified as a notifiable substance, which would automatically **classify the facility a Major Hazard Installation**.

5.2 Power Plant and Associated Equipment

Hazardous substances associated with this facility would include; ammonia; hydrogen, diesel and natural gas. Of the listed substances, only ammonia could result in offsite fatalities.

The risk of $1x10^{-6}$ fatalities per person per year isopleth found to extend beyond the site boundary, and **that alone qualifies the site as a Major Hazard Installation**. The risk of $1x10^{-4}$ fatalities per person per year, representing intolerable to the general public, was found to remain within the site boundary. Reducing the risks, particularly relating to ammonia, could not only reduce the risks of the facility, but could alter the MHI classification of the proposed PRBGP3 facility in Richards Bay.

5.3 Impacts onto Neighbouring Properties, Residential Areas and MHIs

A large release of ammonia could extend a considerable downward distance impacting the commercial and residential areas of Richards Bay. However, fatalities will be limited to the Alton industrial area and will not impact residential areas.

No residential area or vulnerable institutions would be seriously impacted with the construction and operation of the proposed PRBGP3.

5.4 Major Hazard Installation

This investigation concluded that under the current design conditions, the proposed PRBGP3 facility in Richards Bay **would be considered as a Major Hazard Installation** and would require notification in accordance with the MHI regulations.

Kindly note that this study is not intended to replace the Major Hazard Installation risk assessment, which should be completed prior to construction of the terminal once final designs are available.

6 RECOMMENDATIONS

As a result of the risk assessment study conducted for the proposed PRBGP3 facility in Richards Bay, a number of events were found to have risks beyond the site boundary. These risks could be mitigated to acceptable levels, as shown in the report.

RISCOM did not find any fatal flaws that would prevent the project proceeding to the detailed engineering phase of the project, and would support the project under the following conditions most of which will be detailed in the MHI study:

- Compliance with all statutory requirements, i.e., pressure vessel designs;
- Compliance with applicable SANS codes, i.e., SANS 10087, SANS 10089, SANS 10108, etc. ;
- Incorporation of applicable guidelines or equivalent international recognised codes of good design and practice into the designs;
- Completion of a recognised process hazard analysis (such as a HAZOP study, FMEA, etc.) on the proposed facility prior to construction to ensure design and operational hazards have been identified and adequate mitigation put in place;
- Full compliance with IEC 61508 and IEC 61511 (Safety Instrument Systems) standards or equivalent to ensure that adequate protective instrumentation is included in the design and would remain valid for the full life cycle of the tank farm:
    - Including demonstration from the designer that sufficient and reliable instrumentation would be specified and installed at the facility;
- Preparation and issue of a safety document detailing safety and design features reducing the impacts from fires, explosions and flammable atmospheres to the MHI assessment body at the time of the MHI assessment:
    - Including compliance to statutory laws, applicable codes and standards and world's best practice;
    - Including the listing of statutory and non-statutory inspections, giving frequency of inspections;
    - Including the auditing of the built facility against the safety document;
    - Noting that codes such as IEC 61511 can be used to achieve these requirements;
- Demonstration by the PRBGP3 owner or their contractor that the final designs would reduce the risks posed by the installation to the South African requirements as prescribed in SANS 1461 (2018);
- Signature of all terminal designs by a professional engineer registered in South Africa in accordance with the Professional Engineers Act, who takes responsibility for suitable designs;
- Completion of an emergency preparedness and response document for on-site and off-site scenarios prior to initiating the MHI risk assessment (with input from local authorities);
- Any increases to the product list or product inventories must be with the approval of the authorities under NEMA;
- Final acceptance of the facility risks with an MHI risk assessment that must be completed in accordance with the MHI regulations;
    - Basing such a risk assessment on the final design and including engineering mitigation.

Table of Contents

1 INTRODUCTION 1-1
1.1 Legislation 1-1
1.1.1 National Environmental Management Act (No. 107 of 1998) (NEMA) and its Regulations........ 1-1
1.1.2 The Occupational Health and Safety Act No. 85 of 1993........ 1-2
1.2 Terms of Reference........ 1-3
1.3 Purpose and Main Activities 1-4
1.4 Main Hazards Due to Substance and Process........ 1-4
1.5 Software 1-4
1.6 Assumptions and Limitations 1-4
2 ENVIRONMENT 2-1
2.1 General Background........ 2-1
2.2 Meteorology........ 2-2
2.2.1 Surface Winds........ 2-3
2.2.2 Precipitation and Relative Humidity 2-4
2.2.3 Temperature 2-5
2.2.4 Atmospheric Stability........ 2-6
2.2.5 Meteorological Simulation Values 2-8
3 PROJECT DESCRIPTION........ 3-1
3.1 Project Description 3-4
3.2 Fuel and Process Chemicals 3-6
3.2.1 Natural Gas........ 3-6
3.2.2 Diesel........ 3-6
3.2.3 Hydrogen 3-6
3.2.4 Ammonia........ 3-6
3.2.5 Nitrogen 3-6
4 METHODOLOGY 4-1
4.1 Hazard Identification........ 4-1
4.1.1 Notifiable Substances........ 4-2
4.1.2 Substance Hazards........ 4-2
4.1.3 Physical Properties 4-5
4.1.4 Components Excluded from the Study 4-5
4.2 Physical and Consequence Modelling 4-6
4.2.1 Fires........ 4-7
4.2.2 Explosions........ 4-9
4.3 Risk Analysis........ 4-13
4.3.1 Background........ 4-13
4.3.2 Predicted Risk........ 4-14
4.3.3 Generic Equipment Failure Scenarios 4-14
4.4 Risk Criteria........ 4-19
4.4.1 Maximum Individual Risk Parameter 4-19
4.4.2 Acceptable Risks........ 4-19
4.4.3 Land Planning 4-22

4.4.4 Societal Risk Parameter 4-24
4.4.5 Scenario Selection 4-24
5 RISK ASSESSMENT 5-1
5.1 Natural Gas Pipeline 5-1
5.1.1 The Purpose of the Processing Unit 5-1
5.1.2 Hazardous Components 5-1
5.1.3 Consequence Modelling 5-2
5.2 Hydrogen Storage 5-3
5.2.1 The Purpose of the Processing Unit 5-3
5.2.2 Hazardous Components 5-3
5.2.3 Consequence Modelling 5-3
5.2.4 Consequence Modelling 5-4
5.3 Ammonia 5-5
5.3.1 Hazardous Components 5-5
5.3.2 Consequence Modelling 5-5
5.5 Diesel Storage and Offloading 5-9
5.5.1 The Purpose of the Processing Unit 5-9
5.5.2 Hazardous Components 5-9
5.5.3 Consequence Modelling 5-10
5.6 Nitrogen 5-14
5.6.1 Hazardous Components 5-14
5.6.2 Consequence Modelling 5-14
5.7 Combined Site Risk 5-17
5.7.1 Maximum Individual Risk 5-17
6 RISK TREATMENT / REDUCTION 6-1
6.1 Risk Ranking 6-1
6.2 Mitigation 6-3
6.2.1 Ammonia Storage 6-3
6.2.2 Process Hazard Analysis (PHA) 6-3
6.2.3 Ignition Sources 6-3
6.2.4 Emergency Shut Down System (ESD) 6-3
7 IMPACT ASSESSMENT 7-1
7.1 Methodology - Cumulative Impacts 7-2
7.2 Impact Assessment of the proposed PRBGP3 Thermal Generation Facility at Richards Bay 7-3
7.2.1 Natural Gas Pipeline 7-3
7.2.2 Diesel Installation 7-4
7.2.3 Hydrogen Installation 7-5
7.2.4 Ammonia Storage 7-6
7.2.5 Cumulative Impact Assessment 7-7
8 CONCLUSIONS 8-1
8.1 Notifiable Substances 8-1
8.2 Power Plant and Associated Equipment 8-1
8.3 Impacts onto Neighbouring Properties, Residential Areas and Major Hazard Installations 8-2

8.4 Major Hazard Installation 8-2
8.5 Land Planning Restrictions 8-2
9 RECOMMENDATIONS 9-1
10 REFERENCES 10-1
11 ABBREVIATIONS AND ACRONYMS 11-1
12 APPENDIX A: NOTIFICATION OF MAJOR HAZARD INSTALLATION 12-1
13 APPENDIX B: PADHI LAND-PLANNING TABLES 13-1
13.1 Development Type Table 1: People at Work, Parking 13-1
13.2 Development Type Table 2: Developments for Use by the General Public 13-2
13.3 Development Type Table 3: Developments for Use by Vulnerable People 13-6
13.4 Development Type Table 4: Very Large and Sensitive Developments 13-7
14 APPENDIX C: DEPARTMENT OF EMPLOYMENT AND LABOUR 14-1
15 APPENDIX D: SANAS CERTIFICATES 15-1
16 APPENDIX E: MATERIAL SAFETY DATA SHEETS 16-1
16.1 Ammonia 16-1
16.2 Diesel (Dodecane) 16-2
16.3 Hydrogen 16-3
16.4 Natural Gas 16-4

List of Figures

Figure 2-1: Proposed PRBGP3 location within the RBIDZ 1F 2-1
Figure 2-2: Wind analysis for winter and summer variations 2-3
Figure 2-3: Atmospheric stability as a function of wind direction in Richards Bay 2-6
Figure 2-4: Representative weather classes for Richards Bay (2013–2020) 2-7
Figure 3-1: Site layout 3-1
Figure 3-2: Simplified schematic of a CCGT power plant 3-5
Figure 4-1: UK HSE decision-making framework 4-20
Figure 4-2: Town-planning zones for pipelines 4-22
Figure 4-3: Town-planning zones 4-23
Figure 4-4: Airborne vapours from a loss of containment of liquefied gas stored in a pressurised vessel 4-25
Figure 4-5: Event tree for an instantaneous release of a liquefied flammable gas 4-26
Figure 4-6: Event tree for a continuous release of a liquefied flammable gas 4-26
Figure 4-7: Event tree for a continuous release of a flammable gas 4-27
Figure 4-8: Event tree for a continuous release of a flammable liquid 4-27
Figure 5-1: 1% Fatality along the pipeline routing 5-2
Figure 5-2: The extent to the 1% fatality from the worst-case loss of containment of the hydrogen trailer at the northern gas turbine 5-4
Figure 5-3: The extent of the ERPG-2 values of nitrogen following a large release, using the ERPG-2 value (832 000 ppm) 5-6
Figure 5-4: Maximum extent of the 1% fatality for major releases 5-7
Figure 5-5: Thermal radiation from large diesel pool fires at the assumed position at the Northern gas turbine area 5-11
Figure 5-6: Thermal radiation from large diesel pool fires at the road offloading area at the assumed position at the Northern gas turbine area 5-12
Figure 5-7: The extent of the ERPG-2 values of nitrogen following a large release, using the ERPG-2 value (832 000 ppm) 5-15
Figure 5-8: Maximum extent of the 1% fatality for major releases 5-16
Figure 5-9: Lethal probability isopleths associated with the proposed PRBGP3 facility in Richards Bay 5-17
Figure 6-1: Comparison of the 1×10^{-6} fatalities per person per year isopleth for various site installations 6-2

List of Tables

Table 2-1: Long-term average precipitation and relative humidity for Richards Bay...... 2-4
Table 2-2: Long-term temperature averages for Richards Bay 2-5
Table 2-3: Classification scheme for atmospheric stability... 2-6
Table 2-4: Representative weather classes.. 2-7
Table 2-5: Allocation of observations into six weather classes 2-7
Table 2-6: Default meteorological values used in simulations, based on local conditions 2-8
Table 4-1: Flammable and combustible components to be stored on, produced at or delivered to site 4-5
Table 4-2: Representative components... 4-5
Table 4-3: Components excluded from the study 4-5
Table 4-4: Thermal radiation guidelines (BS 5980 of 1990)... 4-7
Table 4-5: Summary of consequences of blast overpressure (Clancey 1972) 4-10
Table 4-6: Damage caused by overpressure effects of an explosion (Stephens 1970)... 4-11
Table 4-7: Influence of public perception of risk on acceptance of that risk, based on the POST report 4-13
Table 4-8: Failure frequencies for atmospheric vessels.. 4-15
Table 4-9: Failure frequencies for pressure vessels 4-15
Table 4-10: Failure frequencies for process pipes.. 4-15
Table 4-11: Failure frequency for centrifugal pumps and compressors........................ 4-16
Table 4-12: Failure frequency for reciprocating pumps and compressors.................... 4-16
Table 4-13: Failure frequencies for loading and offloading arms and hoses 4-16
Table 4-14: Human failure rates of specific types of tasks (CPR 12E 2005; Red Book).. 4-17
Table 4-15: Probability of direct ignition for stationary installations (RIVM 2009).......... 4-18
Table 4-16: Classification of flammable substances.. 4-18
Table 4-17: Land-use decision matrix.. 4-23
Table 5-1: Scenarios modelled for the hydrogen trailer 5-3
Table 5-2: Scenarios modelled for the ammonia transport pipeline and storage........... 5-5
Table 5-3: Maximum distance to 1% fatality from the point of release 5-8
Table 5-4: Scenarios modelled for the diesel transport pipeline, pumps and storage . 5-10
Table 5-5: Maximum distance to 1% fatality from the point of release 5-13
Table 5-6: Scenarios modelled for the nitrogen transport pipeline and storage 5-14
Table 7-1: Impact Assessment of natural gas pipeline 7-3
Table 7-2: Impact Assessment of Diesel Installations.. 7-4
Table 7-3: Impact Assessment of Diesel Installations.. 7-5
Table 7-4: Impact Assessment of ammonia storage.. 7-6
Table 7-5: Cumulative impact of project as a whole 7-7

QUANTITATIVE RISK ASSESSMENT OF THE PROPOSED PRBGP3 AT RICHARDS BAY, KWAZULU NATAL

1 INTRODUCTION

Phakwe Richards Bay Gas Power 3 (Pty Ltd) proposes to operate a combined cycle gas power plant (hereinafter referred to as PRBGP3) of up to 2000 MW nominal capacity that will operate on natural gas (in either liquid or gas forms) or a mixture of natural gas and hydrogen (in a proportion scaling up from 30% hydrogen - H_2) which will be transported to the site via a pipeline.

The Project site is to be located Municipally within the Richards Bay Industrial Development Zone 1F (RBIDZ 1F), situated North of the Richards Bay centre, which falls within the jurisdiction of the City of uMhlathuze Local Municipality and the King Cetshwayo District Municipality in the KwaZulu-Natal Province.

Since off-site incidents may result due to hazards of some of the chemical components to be stored on, produced at or delivered to site, RISCOM (PTY) LTD was commissioned to conduct a quantitative risk assessment (QRA), the impacts onto surrounding properties and communities as part of an environmental impact assessment (EIA).

1.1 Legislation

Legislation discussed in this subsection is limited to the health and safety of employees and the public.

Risk assessments are conducted when required to do so by law, or by companies wishing to determine the risks of the facility for other reasons, such as insurance.

In South Africa, risk assessments are carried out under the legislation of two separate acts, each with different requirements. These are discussed in the subsections that follow.

1.1.1 National Environmental Management Act (No. 107 of 1998) (NEMA) and its Regulations

The National Environmental Management Act (NEMA) contains South Africa's principal environmental legislation. It has, as its primary objective to make provision for cooperative governance by establishing principles for decision making on matters affecting the environment, on the formation of institutions that will promote cooperative governance and on establishing procedures for coordinating environmental functions exercised by organs of state, as well as to provide for matters connected therewith (Government Gazette 1998).

Section 30 of the NEMA act deals with the control of emergency incidents where an "*incident*" is defined as an "*unexpected sudden occurrence, including a major emission, fire or explosion leading to serious danger to the public or potentially serious pollution of or detriment to the environment, whether immediate or delayed*".

The act defines "*pollution*" as *"any change in the environment caused by:*

(i) Substances;
(ii) Radioactive or other waves; or,
(iii) Noise, odours, dust or heat…

" *Emitted from any activity, including the storage or treatment of waste or substances, construction and the provision of services, whether engaged in by any person or an organ of state, where that change has an adverse effect on human health or wellbeing or on the composition, resilience and productivity of natural or managed ecosystems, or on materials useful to people, or will have such an effect in the future…* "

"*Serious*" is not fully defined but would be accepted as having long lasting effects that could pose a risk to the environment, or to the health of the public that is not immediately reversible.

This is similar to the definition of a MHI as defined in the Occupational Health and Safety Act (OHS Act) 85 of 1993 and its MHI regulations.

Section 28 of NEMA makes provision for anyone who causes pollution or degradation of the environment being made responsible for the prevention of the occurrence, continuation or reoccurrence of related impacts and for the costs of repair of the environment. In terms of the provisions under Section 28 that are stated as:

" *Every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such harm to the environment is authorised by law or cannot reasonably be avoided or stopped…* "

1.1.2 The Occupational Health and Safety Act No. 85 of 1993

The Occupation Health and Safety Act 85 (1993) is primarily intended for the health and safety of the employees, whereas its MHI regulations is intended for the health and safety of the public.

The OHS Act shall not apply in respect of:

" *a) A mine, a mining area or any works as defined in the Minerals Act, 1991 (Act No. 50 of 1991), except in so far as that Act provides otherwise;*

b) Any load line ship (including a ship holding a load line exemption certificate), fishing boat, sealing boat and whaling boat as defined in Section 2 (1) of the Merchant Shipping Act, 1951 (Act No. 57 of 1951), or any floating crane, whether or not such ship, boat or crane is in or out of the water within any harbour in the Republic or within the territorial waters thereof, (date of commencement of paragraph (b) to be proclaimed.), or in respect of any person present on or in any such mine, mining area, works, ship, boat or crane. "

1.1.2.1 Major Hazard Installation Regulations

The MHI regulations (July 2001) published under Section 43 of the OHS Act require employers, self-employed persons and users who have on their premises, either permanently or temporarily, a major hazard installation or a quantity of a substance which may pose a **risk** (our emphasis) that could affect the health and safety of employees and the public to conduct a risk assessment in accordance with the legislation.

In accordance with legislation, the risk assessment must be done **prior to construction of the facility** by an approved inspection authority (AIA; see Appendix C and Appendix D), registered with the Department of Employment and Labour and accredited by the South African Accreditation Systems (SANAS).

Similar to Section 30 of NEMA as it relates to the health and safety of the public, the MHI regulations are applicable to the health and safety of employees and the public in relation to the operation of a facility, and specifically in relation to sudden or accidental major incidents involving substances that could pose a risk to the health and safety of employees and the public.

The notification of the MHI is described in the regulations as an advertisement placement and specifies the timing of responses from the advertisement. It should be noted that the regulation does not require public participation.

The regulations, summarised in Appendix A, essentially consists of six parts, namely:

1. The duties for notification of a MHI (existing or proposed), including:
    a. Fixed;
    b. Temporary installations;
2. The minimum requirements for a quantitative risk assessment (QRA);
3. The requirements for an on-site emergency plan;
4. The reporting steps for risk and emergency occurrences;
5. The general duties required of suppliers;
6. The general duties required of local government.

As this is not an MHI risk assessment, the application of the above legislation is not mandatory but the legislation is described to give a background to this report.

1.2 Terms of Reference

The main aim of the investigation was to quantify the risks to employees, neighbours and the public with regard to the proposed PRBGP3 facility at Richards Bay.

This risk assessment was conducted in accordance with the MHI regulations and can be used as notification for the facility. The scope of the risk assessment included:

1. Development of accidental spill and fire scenarios for the facility;
2. Using generic failure rate data (for tanks, pumps, valves, flanges, pipework, gantry, couplings and so forth), determination of the probability of each accident scenario;
3. For each incident developed in Step 2, determination of consequences (such as thermal radiation, domino effects, toxic-cloud formation and so forth);

4. For scenarios with off-site consequences (greater than 1% fatality off-site), calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality.

1.3 Purpose and Main Activities

The main activity of the proposed PRBGP3 facility in Richards Bay would be the generation of mid-merit power supply to the South African electricity grid. The fuel used to generate power would be LPG, that will be delivered to site by truck.

1.4 Main Hazards Due to Substance and Process

The main hazards that would occur with a loss of containment of hazardous components at the proposed PRBGP3 facility in Richards Bay include exposure to:

- Thermal radiation from fires;
- Overpressure from explosions.

1.5 Software

Physical consequences were calculated using Gexcon's RISKCURVES v. 11.5.1. All calculations were performed by Mr M P Oberholzer.

1.6 Assumptions and Limitations

The risk assessment was based on the conceptual designs of the facility, excluding the details still to be determined from the detailed designs. Furthermore, EIAs are intended to suggest mitigation which may alter the design and layout of the project. It is thus understood that detailed designs would be required to complete the project for construction.

RISCOM used the information provided and made engineering assumptions as described in the document for the purposes of compiling this quantitative risk assessment. The accuracy of the document would be limited to the available documents presented for the completion of this report. However, the inventory of hazardous goods of the facility is not expected to increase from the amounts stated in this document and despite the potential of an improved site layout, we expect the maximum impacts to be representative.

With the detailed designs, we expect additional mitigation, which should reduce the risks as recommended.

The greatest impact on accuracy would be omissions from the design presented, changes to the process, substitution of hazards goods (typically), as required by the equipment supplier or the increase of hazardous goods inventory. These would be evaluated under the Major Hazardous Installation regulations, prior to construction.

The risk assessment excludes the following:

- Natural events, such as earthquakes and floods;
- Ecological risk assessment;
- An emergency plan.

2 ENVIRONMENT

2.1 General Background

The site location for the proposed PRBGP3 facility is on 16820, 16819,1/16674 and a subdivision of erf 17442 within the Richards Bay IDZ Zone 1F, and will occupy approximately 11.8 ha, as shown in Figure 2-1.

The white lines indicated the boundary of the RBIDZ 1F, with the entrance located to the east.

RBGP3 in Richards Bay is approximately 8 km from the deep-sea port.

Figure 2-1: Proposed PRBGP3 location within the RBIDZ 1F

The RBIDZ 1F is an industrial zoned park that has an access control point, whereby all traffic and people are controlled. Thus, all people entering the site will be limited to workers, and the general public will not have access to free movement within the zoned area.

The land use surrounding the proposed PRBGP3 facility is shown in Figure 2-1.

The closest residential area is Wild En Wiede lying approximately 2.5 km from the proposed PRBGP3 facility.

2.2 Meteorology

Meteorological mechanisms govern dispersion, transformation and eventual removal of hazardous vapours from the atmosphere. The extent to which hazardous vapours will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer.

Dispersion comprises of vertical and horizontal components of motion. The stability and the depth of the atmosphere from the surface (known as the mixing layer) define the vertical component. The horizontal dispersion of hazardous vapours in the atmospheric boundary layer is primarily a function of the wind field. Wind speed determines both the distance of downwind transport and the rate of dilution as a result of stretching of the plume, and generation of mechanical turbulence is a function of the wind speed in combination with surface roughness. Wind direction and variability in wind direction, both determine the general path hazardous vapours will follow and the extent of crosswind spreading.

Concentration levels of hazardous vapours therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing layer depth and to shifts in the wind field.

For this report, the meteorological conditions at Richards Bay, as measured by the South African Weather Service, were used as the basis of wind speed, direction and atmospheric stability.

The long-term rainfall, humidity and temperature used a 30-year average for Richards Bay, as measured by the South African Weather Service.

2.2.1 Surface Winds

Hourly averages of wind speed and direction recorded at Richards Bay were obtained from the South African Weather Service for the period from the 1st of January 2013 to the 31st of January 2020.

The predominant winds blow from the north and southwest quadrants, with calm conditions occurring up to 2.4% of the time. Low to medium wind speeds are predominant, with wind speeds of more than 8.7 m/s occurring about 1.4% of the time.

Although, wind shifts between the north-easterly and south-westerly sectors occur all the months of the year, the frequency with which such wind shifts occur varies seasonally as a function of synoptic climatology. The predominant weather directions for the summer and winter months are the north and north-easterly winds with westerly and easterly winds occurring less frequently, as shown in Figure 2-2.

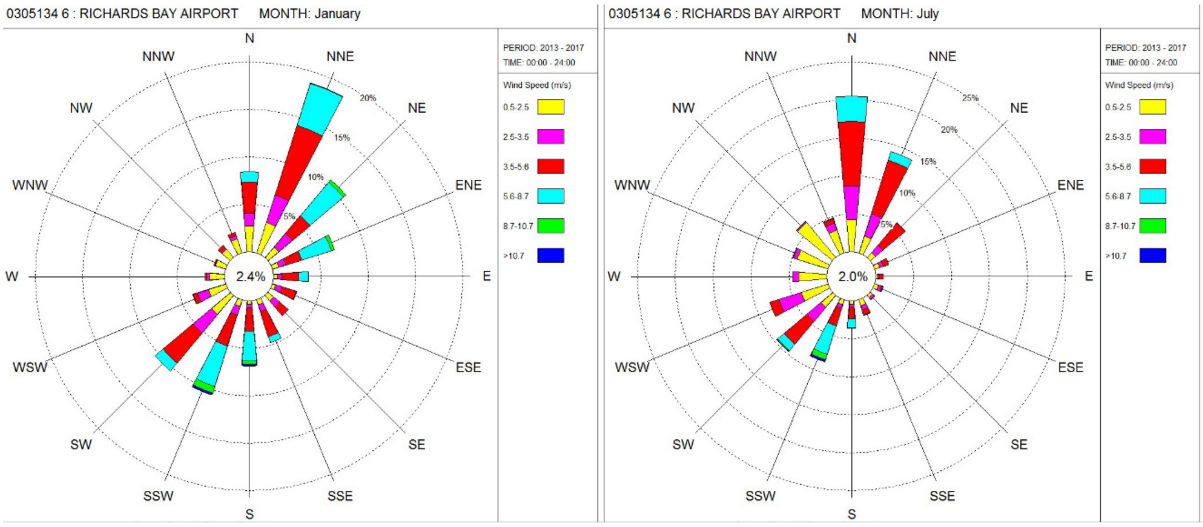


Figure 2-2: Wind analysis for winter and summer variations

2.2.2 Precipitation and Relative Humidity

The long-term rainfall and relative humidity recorded at Richards Bay was obtained from the South African Weather Service for the period from 1994 to 2020.

Relative humidity, the amount of water that is contained in the atmosphere, influences the extent of fires and toxic clouds. The warmer the air, the more moisture it can hold. Should the relative humidity reach 100%, precipitation occurs. The long-term average precipitation and humidity supplied by the South African Weather Service in Table 2-1, indicates an average annual relative humidity in excess of 50%.

Table 2-1: Long-term average precipitation and relative humidity for Richards Bay

Month	Average Precipitation (mm)	Relative Humidity at 14H00 (%)	Relative Humidity at 20H00 (%)
January	172	70	79
February	167	71	79
March	107	71	78
April	109	71	81
May	109	63	79
June	57	61	72
July	60	59	74
August	65	59	74
Sept	77	66	73
October	105	67	79
November	114	70	80
December	86	69	79
Year	**1228**	**67**	**79**

2.2.3 Temperature

Air temperature is important for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), for estimating evaporation rates and for determining the development of the mixing and inversion layers.

The long-term temperatures recorded at Richards Bay were obtained from the South African Weather Service for the period from 1994 to 2020, as given in Table 2-2. Extreme temperatures frequently occur due to berg wind conditions, during which temperatures over 40°C are reported for all months of the year.

Table 2-2: Long-term temperature averages for Richards Bay

Month	Average Maximum (°C)	Average Minimum (°C)	Mean Average (°C)
January	29.2	21.2	25.2
February	28.9	21.2	25
March	28.9	20.4	24.6
April	27	18.1	22.5
May	24.8	15.2	20
June	23.1	12.3	17.7
July	23	12.3	17.6
August	24	14.1	19
September	24.9	16	20.3
October	25.4	17.3	21.3
November	26.7	18.6	22.7
December	28.7	20.4	24.5
Year	**26.2**	**17.3**	**21.7**

2.2.4 Atmospheric Stability

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 2-3. The atmospheric stability, in combination with the wind speed, is important in determining the extent of a pollutant from a release.

A very stable atmospheric condition, typically at night, would have a low wind speed and produce the greatest endpoint for a dense gas. Conversely, a buoyant gas would have the greatest endpoint distance at a high wind speed.

Table 2-3: Classification scheme for atmospheric stability

Stability Class	Stability Classification	Description
A	Very unstable	Calm wind, clear skies, hot daytime conditions.
B	Moderately unstable	Clear skies, daytime conditions.
C	Unstable	Moderate wind, slightly overcast daytime conditions.
D	Neutral	Strong winds or cloudy days and nights.
E	Stable	Moderate wind, slightly overcast night-time conditions.
F	Very stable	Low winds, clear skies, cold night-time conditions.

The atmospheric stability for Richards Bay, as a function of the wind class, was calculated from hourly weather values supplied by the South African Weather Service from the 1st of January 2013 to the 31st of January 2020, as given in Figure 2-3.

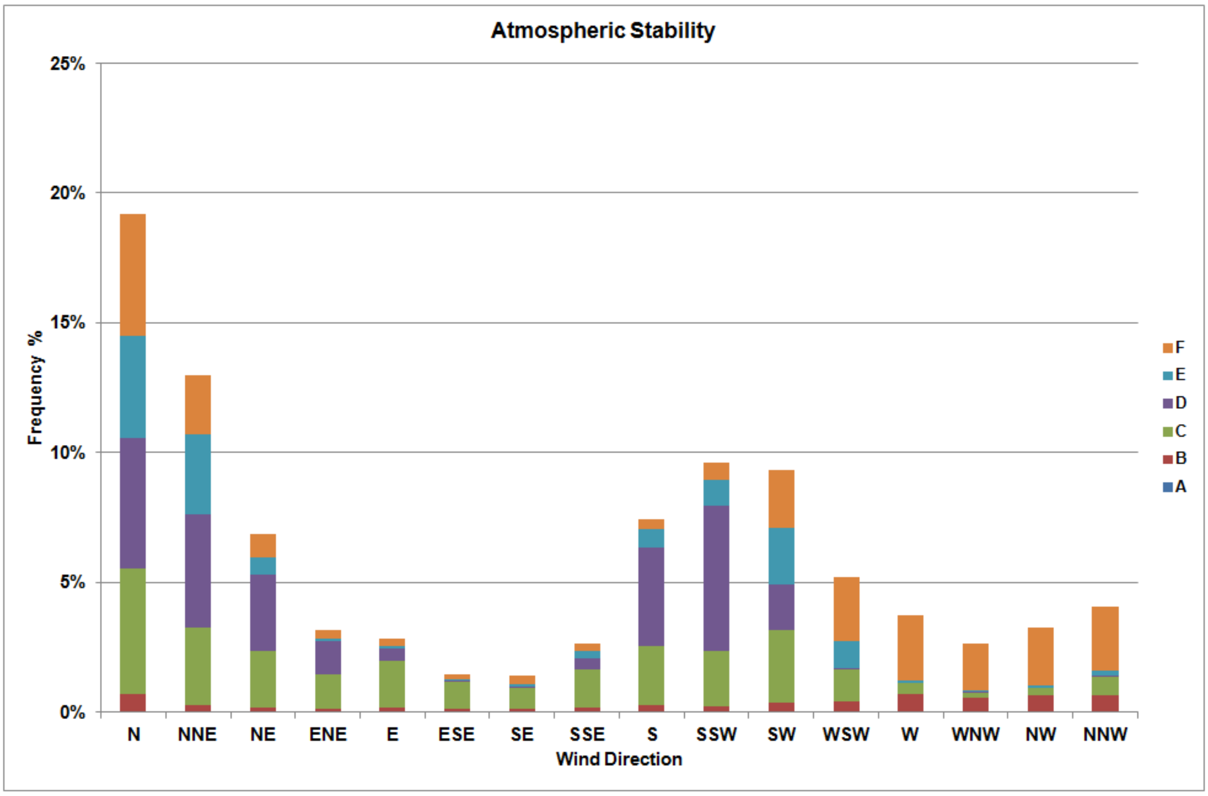


Figure 2-3: Atmospheric stability as a function of wind direction in Richards Bay

This risk assessment's calculations are based on six representative weather classes covering the stability conditions of stable, neutral and unstable as well as low and high wind speeds. In terms of Pasquill classes, the representative conditions, are given in Table 2-4.

Table 2-4: Representative weather classes

Stability Class	Wind (m/s)
B	3
D	1.5
D	5
D	9
E	5
F	1.5

The allocation of observations into the six weather classes is summarised in Table 2-5, with the representative weather classes, given in Figure 2-4.

Table 2-5: Allocation of observations into six weather classes

Wind Speed	A	B	B/C	C	C/D	D	E	F
< 2.5 m/s	B 3 m/s			D 1.5 m/s			F 1.5 m/s	
2.5 - 6 m/s				D 5 m/s			E 5 m/s	
> 6 m/s				D 9 m/s				

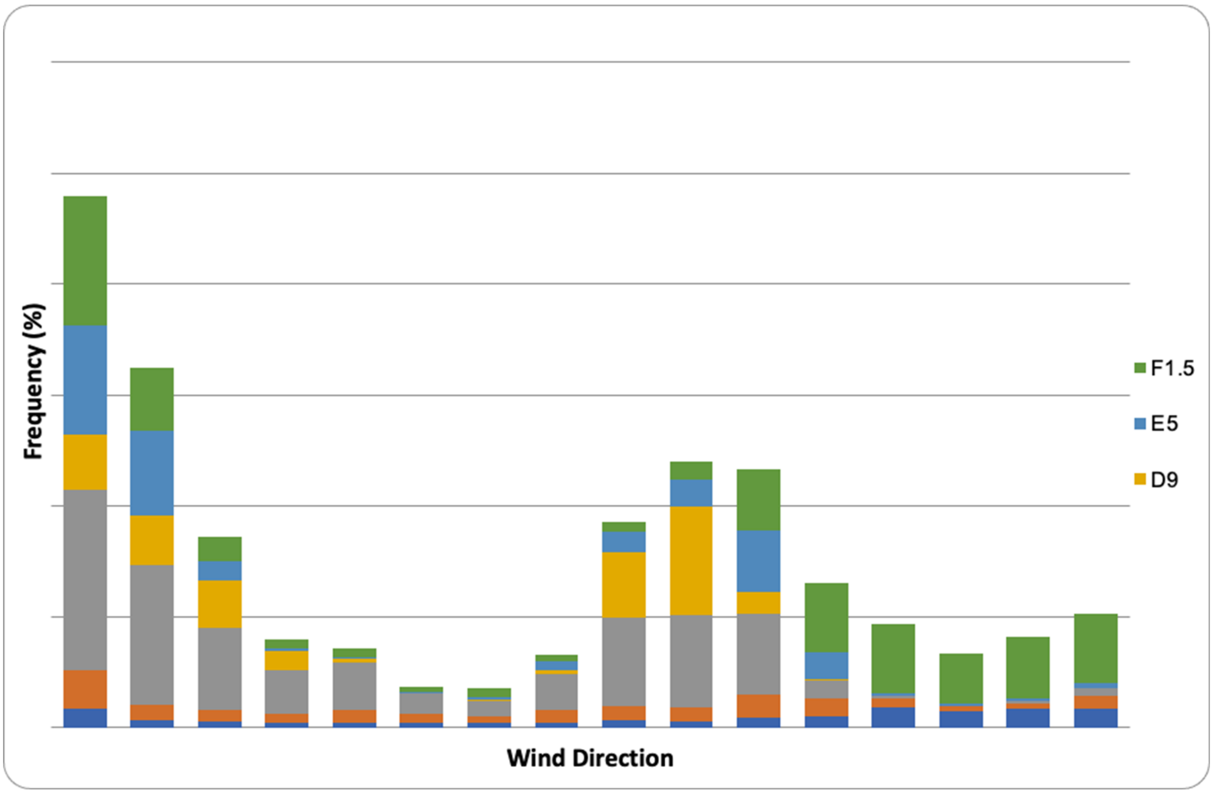


Figure 2-4: Representative weather classes for Richards Bay (2013–2020)

2.2.5 Meteorological Simulation Values

Default meteorological values used in simulations, based on local conditions, are given in Table 2-6.

Table 2-6: Default meteorological values used in simulations, based on local conditions

Parameter	Default Value Daytime	Default Value Night-time
Ambient temperature (°C)	26	17
Substrate/bund temperature (°C)	22	22
Water temperature (°C)	22	22
Air pressure (bar)	1.013	1.013
Humidity (%)	67	78
Fraction of a 24-hour period	0.5	0.5
Mixing height	[1]	[1]

1 The mixing height is calculated as part of the software

3 PROJECT DESCRIPTION

The proposed PRBGP3 facility in Richards Bay is to consist offices, workshops, gas and steam turbines and associated equipment, as shown in Figure 3-1.

The site will be accessed via the main entrance of the RBIDZ 1F. Thus, all unauthorised people and the general public will be excluded from the RBIDZ 1F.

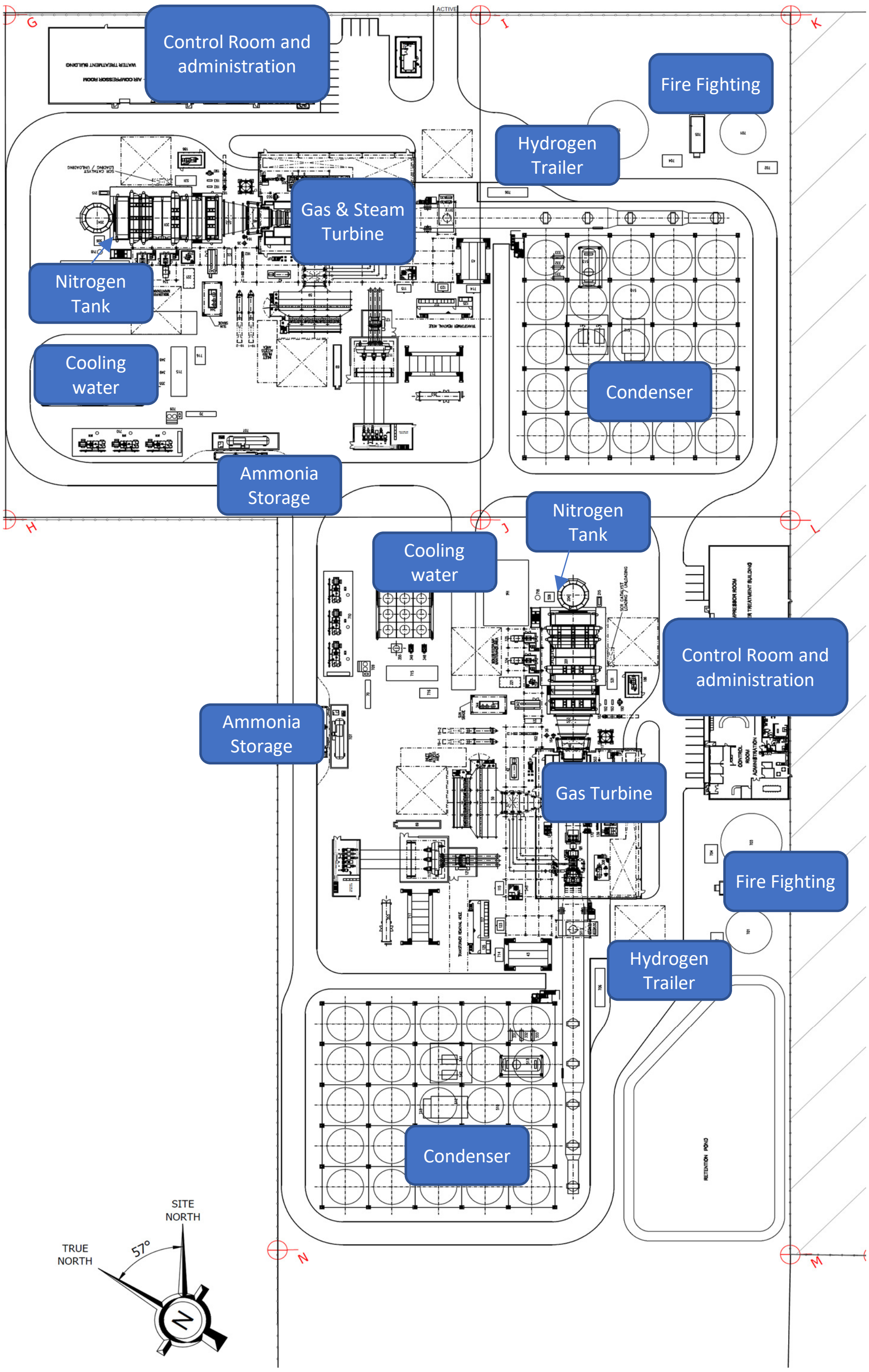


Figure 3-1: Site layout

The power plant will operate at mid-merit to baseload duty and will include the following main infrastructure:

- Up to 4 gas turbines for the generation of electricity through the use of natural gas (liquid or gas forms), or a mixture of Natural gas and Hydrogen (in a proportion scaling up from 20% H_2) as fuel source, operating all turbines at mid-merit or baseload (estimated 16 to 24 hours daily operation).
- Exhaust stacks associated with each gas turbine.
- Up to 4 Recovery Steam Generator (HRSG to generate steam by capturing the heat from the turbine exhaust).
- Up to 4 steam turbines to generate additional electricity by means of the steam generated by the HRSG.
- The water treatment plant will demineralise incoming water from municipal or similar supply, to the gas turbine and steam cycle requirements. The water treatment plant will produce two parts demineralised water and reject one-part brine, which will be discharged to the RBIDZ stormwater system.
- Steam turbine water system will be a closed cycle with air cooled condensers. Make-up water will be required to replace blow down.
- Air cooled condensers to condensate used steam from the steam turbine.
- Compressed air station to supply service and process air.
- Water pipelines and water tanks for storage and distributing of process water. (Potential sourcing of alternative water outside RBIDZ supply (Municipality)).
- Water retention pond.
- Closed Fin-fan coolers to cool lubrication oil for the gas turbines.
- Gas generator Lubrication Oil System.
- Gas pipeline supply conditioning process facility. Please note, gas supply will be via dedicated pipeline from the proposed Transnet supply pipeline network of Richards Bay (the location of this network has not yet been confirmed) or, alternatively directly from the Regasification facilities at the Richards Bay Harbour. The gas pipeline will be separately authorized.
- Site water facilities including potable water, storm water and waste water.
- Fire water (FW) storage and FW system.
- Diesel emergency generator for start-up operation.
- Onsite fuel conditioning including heating system.
- All underground services: This includes stormwater and wastewater.
- Ancillary infrastructure including:
    - Roads (access and internal);
    - Warehousing and buildings;
    - Workshop building;
    - Fire water pump building;
    - Administration and Control Building;
    - Ablution facilities;
    - Storage facilities;
    - Guard House;
    - Fencing;
    - Maintenance and cleaning area;
    - Operational and maintenance control centre;

- Electrical facilities including:
  - Power evacuation including GCBs, GSU transformers, MV busbar, HV cabling and 1 x 275kV or 400kV GIS Power Plant substation.
  - Generators and auxiliaries;
- Service infrastructure including:
  - Stormwater channels;
  - Water pipelines;
  - Temporary work areas during the construction phase (laydown areas).

A dedicated pipeline to connect into an on-site gas receiving and conditioning station will provide the natural gas or the mixture of natural gas and Hydrogen. The pipeline will be connected to the proposed Transnet supply pipeline network of Richards Bay (the location of this network has not yet been confirmed), or it will extend directly to the Regasification facilities in the Richards Bay Harbour. A separate EIA process will be undertaken for the dedicated fuel-supply pipeline.

3.1 Project Description

The project will consist of up to 4 closed cycle gas turbines (CCGT) used to produce a nominal capacity of 2000 MW power from natural gas (in either liquid or gas forms), or a mixture of natural gas and hydrogen (in a proportion scaling up from 30% hydrogen - H_2) as a fuel.

The process for converting the energy in a fuel into the electric power involves the creation of mechanical work, which is then transformed into the electric power by a generator. The overall efficiency of the conversion depending on the type of fuel and the thermodynamics process used and it can be as low as 30%.

To increase the overall efficiency of electric power plants, multiple thermodynamic processes can be introduced or combined to recover and utilize the residual heat energy in hot exhaust gases. By the use of combined cycle, power plants can achieve the electrical efficiency up to 60%.

The terms “combined cycle” refers to the combining of multiple thermodynamic cycles to generate electric power. Combined cycle operation uses a heat recovery steam generator (HRSG) that captures the heat from high temperature exhaust gases to produce steam, which is then supplied to a steam turbine to generate additional electric power. The process for creating steam to produce work using a steam turbine is based on the Rankine cycle.

The most common type of combined cycle power plant utilizes gas turbines and is called a combined cycle gas turbine (CCGT) plant. Because gas turbines have low efficiency in simple cycle operation and the output produced by the steam turbine accounts for about half of the CCGT plant output.

The simplified schematic of the (CCGT) power plant is shown in Figure 3-2, and consists of the following steps that are carried out in combined-cycle plants to produce electricity, including the capturing of the wastage heat from the gas turbine to increase efficiency and electrical output.

1. Gas turbine burns fuel (gas):
    - The gas turbine compressed the air and mixed it with fuel that is heated to a very high temperature. Then the hot air-fuel mixture moves through the gas turbine blades, making them spin.
    - The fast-spinning of turbine drives a generator that converts a portion of the spinning energy into electricity.
2. Heat recovery system captures exhaust (HRSG):
    - A Heat Recovery Steam Generator (HRSG) captures the exhaust heat energy from the gas turbine that would otherwise escape through the exhaust stack / chimney.
    - The HRSG helps to creates steam from the gas turbine exhaust heat and it delivers to the steam turbine.
3. Steam turbine delivers additional electricity:
    - The steam turbine sends its energy to the generator drive shaft, where it is converted into additional electricity.

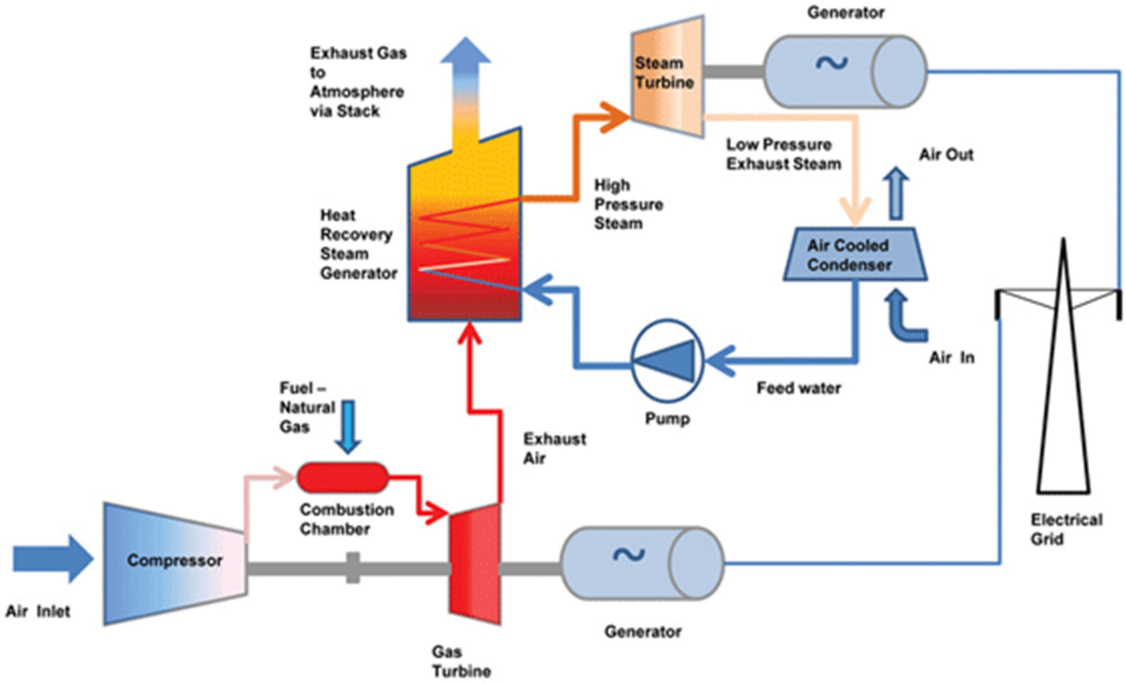


Figure 3-2: Simplified schematic of a CCGT power plant

3.2 Fuel and Process Chemicals

3.2.1 Natural Gas

Natural gas would be used to fuel the gas turbines. The gas will be supplied via a pipeline at an estimated flow rate of 5570 Nm^3/hr per gas turbine. This study assumes a gas supply pressure of 60 bar and 1ºC - 10ºC. No storage of natural gas would be provided.

3.2.2 Diesel

An 80 m^3 diesel storage tank would be provided for emergency power. At this stage of the design, the diesel storage tank location is unknown.

3.2.3 Hydrogen

One hydrogen trailer per gas turbine has been provided in the design. The trailer is assured to be that of a standard hydrogen trailer of 190 kg hydrogen inventory with a storage pressure at 225 bar(g).

3.2.4 Ammonia

Ammonia would be used to adjust the pH of the boiler water feed. The size and storage details of the ammonia has not been provided. However, the ammonia tank dimensions measured from the layout provided a 60 m^3 ammonia tank per gas turbine.

3.2.5 Nitrogen

Nitrogen would be required to purge natural gas in pipelines and equipment prior to conducting maintenance.

The nitrogen designs have not been specified at this stage of the project. This study assumes a single 30 m^3 cryogenic storage tank will be used.

4 METHODOLOGY

Risk assessments done in accordance with the MHI regulations are required to be conducted according to SANS 1461 (2018). This standard is specific to the MHI risk assessment that is required to be done prior to construction and includes elements that are not usually available at the preparation stage of a project, such as emergency plans and mitigation suggested during the EIA process.

SANS 1461 (2018) is based on RIVM (2009) for process plants. The latter standards describe the minimum scenarios to be included in the assessment, as well as the assumptions to be used. As full compliance of SANS 1461 (2018) cannot be achieved within the NEMA legislative framework, general compliance of the aforementioned standards at this stage would be applicable and briefly described in the sections below. This general compliance assessment constitutes a quantitative risk assessment (QRA).

The QRA process is summarised with the following steps:

1. Identification of components that are flammable, toxic, reactive or corrosive and that have potential to result in a major incident from fires, explosions or toxic releases;
2. Development of accidental loss of containment (LOC) scenarios for equipment containing hazardous components (including release rate, location and orientation of release);
3. For each incident developed in Step 2, determination of consequences (such as thermal radiation, domino effects, toxic-cloud formation and so forth);
4. For scenarios with off-site consequences (greater than 1% fatality off-site), calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality.

4.1 Hazard Identification

The first step in any risk assessment is to identify all hazards. The merit of including a hazard for further investigation is then determined by how significant it is, normally by using a cut-off or threshold value.

Once a hazard has been identified, it is necessary to assess it in terms of the risk it presents to the employees and the neighbouring community. In principle, both probability and consequence should be considered but there are occasions where, if either the probability or the consequence can be shown to be sufficiently low or sufficiently high, decisions can be made based on just one factor.

During the hazard identification component of the report, the following considerations are taken into account:

- Chemical identities;
- Location of on-site installations that use, produce, process, transport or store hazardous components;
- Type and design of containers, vessels or pipelines;
- Quantity of material that could be involved in an airborne release;
- Nature of the hazard most likely to accompany hazardous materials spills or releases, e.g., airborne toxic vapours or mists, fires or explosions, large quantities to be stored and certain handling conditions of processed components.

The evaluation methodology assumes that the facility will perform as designed in absence of unintended events, such as component and material failures of equipment, human errors, external events and process unknowns.

4.1.1 Notifiable Substances

The General Machinery Regulation 8 and its Schedule A on notifiable substances, requires any employer who has a substance equal to or exceeding the quantity listed in the regulation to notify the divisional director. A site is classified as a Major Hazard Installation if it contains one or more notifiable substances, or if the off-site risk is sufficiently high. The latter can only be determined from a quantitative risk assessment.

The notifiable threshold for ammonia is listed 20 t in a single vessel. As the proposed installation exceeds the threshold limit, ammonia will be classified as a notifiable substance, which would automatically **classify the facility a Major Hazard Installation**.

4.1.2 Substance Hazards

All components on site were assessed for potential hazards according to the criteria discussed in this section.

4.1.2.1 Chemical Properties

A short description of bulk hazardous components to be stored on, produced at or delivered to site is given in the following subsections. The material safety data sheets (MSDSs) of the respective materials are attached in Appendix E.

- **Ammonia**

Ammonia is a colourless gas with a pungent and suffocating odour. It liquefies easily under pressure, with a normal boiling point of -33°C. Although classified as a non-flammable gas, it will burn in 16–25% vapour concentrations in air when exposed to open flames.

It is incompatible with certain materials. It is corrosive to copper, brass, silver, zinc and galvanized steel. Contact with strong oxidizers can result in fires and explosions. It forms explosive products when in contact with calcium hypochlorite (household) bleaches, halogens, gold, mercury and silver. Heat is generated when ammonia dissolves in water. At high temperatures, ammonia emits hydrogen and nitrogen. Products of combustion include nitrogen and water, which are harmless to life and the environment.

The effects of anhydrous ammonia upon the human body vary with the size and weight of the subject and to a lesser extent temperature and humidity.

Contact with liquid ammonia can cause frostbite. Ammonia is soluble in water, forming a corrosive liquid. It is toxic if swallowed or inhaled and can irritate or burn skin, eyes, the nose or the throat at levels as low as 35 ppm but normally at 100–125 ppm, through inhalation or direct contact. At 700 ppm it can cause serious and permanent injury with extreme rapidity.

Upon contact with moist mucosal membranes (such as those in the skin, eyes and respiratory tract), ammonia reacts with water to form a strong alkali, ammonium hydroxide. This causes

severe damage to the surface of tissues, thereby exposing more tissue to the effects of the alkali. Symptoms are rapid on contact due to the high-water solubility of ammonia and include immediate burning of the eyes, nose and throat and coughing and bronchospasm with wheezing and pulmonary oedema (fluid around the lungs).
Massive exposures can override the absorptive surface area of the upper respiratory tract and result in extensive injury to the lower airways and lung tissue.

There have been a number of major accidents involving ammonia involving storage tanks and pipelines as well as ammonia transported on trucks, railcars and ships.

The worst incident occurred in 1973 in Potchefstroom, South Africa, where a failure of an ammonia tank released approximately 39 t killing 18 people.

There have been a number of nonfatal releases of ammonia. A release of about 600 t of ammonia occurred from a pipeline in Floral, Arkansas, in 1971 and resulted in a fish kill but no injuries. In another incident, 230 t of ammonia was released from a pipeline at McPherson, Kansas, without fatalities.

- **Diesel**

Diesel is a hydrocarbon mixture with variable composition, with a boiling-point range of between 252°C and 371°C. It is a pale-yellow liquid with a petroleum odour. Due to the flash point of diesel between 38°C and 65°C, this material is not considered highly flammable but will readily ignite under suitable conditions.

Diesel is stable under normal conditions. It will react with strong oxidising agents and nitrate compounds. This reaction may cause fires and explosions.

Diesel is not considered a toxic material. Contact with vapours may result in slight irritation to nose, eyes and skin. Vapours may cause headache, dizziness, loss of consciousness or suffocation as well as lung irritation with coughing, gagging, dyspnoea, substernal distress and rapidly developing pulmonary oedema.

If swallowed, diesel may cause nausea or vomiting, swelling of the abdomen, headache, CNS depression, coma and death.

The long-term effects of diesel exposure have not been determined. However, this may affect the lungs and may cause the skin to dry out and become cracked.

Diesel floats on water and can result in environmental hazards with large spills into waterways. It is harmful to aquatic life in high concentrations.

- **Hydrogen**

Hydrogen is a colourless odourless gas that is flammable over a wide range of air or vapour concentrations. The vapour forms an explosive mixture with air. Vapours or gases may travel considerable distances to an ignition source and flash back.

Leaking hydrogen may ignite in the absence of any normally apparent source of ignition and, if so, burns with a practically invisible flame that can instantly injure anyone coming in contact with it. Hydrogen gas is very light and rises rapidly in the air. Concentrations may collect in the upper portions of buildings. The liquid can solidify air and may create an explosion hazard.

The very cold gas, as it comes from the liquid, is slightly heavier than air and may remain near ground level until it warms up. Fog formed when the cold gas contacts atmospheric moisture indicates where the gas is spreading but flammable mixtures may exist beyond the visible fog. Explosive atmospheres may linger. Under prolonged exposure to fire or intense heat the containers may rupture violently and rocket.

It is incompatible with oxygen, oxidising agents, air, lithium and halogens. It may react explosively at elevated temperatures or with heating, alkali metals, halogens, oxygen, oxidizers, oxides, ozone, chlorides, dichlorides and trichlorides of nitrogen and unsaturated hydrocarbons. Divided platinum and some other metals will cause a mixture of hydrogen and oxygen to explode at ordinary temperatures. Embrittlement of steel and other metals such as nickel and copper-nickel alloys will occur at ambient temperatures on exposure to the gas at high pressures.

It is not toxic but is a simple asphyxiant by the displacement of oxygen in the air. Exposure to the liquid may result in frostbite.

- **Natural Gas**

The composition of natural gas is primarily methane (±95% v/v), with other components including ethane, propane and nitrogen.

Given the flammable and potentially explosive nature of natural gas, fires and vapour cloud explosions represent the primary hazards associated with transfer of the gas. The gas is a fire and explosion hazard when it is exposed to heat and flame. The lower explosive limit (LEL) is 5% v/v (meaning 5% gas to 95% air, measured by volume) and the upper explosive limit (UEL) is 15% v/v. In unconfined atmospheric conditions, the likelihood of an explosion is expected to be small.

It is not compatible with strong oxidants and could result in fires and explosions in the presence of such materials.

It is nontoxic and would be considered as an asphyxiant only. Chronic and long-term effects are low and are not listed.

4.1.2.2 Corrosive Liquids

Corrosive liquids considered under this subsection, are those components that have a low or high pH and that may cause burns if they come into contact with people or may attack and cause failure of equipment.

Ammonia would be considered corrosive, but is analysed as a toxic component.

4.1.2.3 Reactive Components

Reactive components are components that when mixed or exposed to one another react in a way that may cause a fire, explosion or release a toxic component.

All components to be stored on, produced at or delivered to site are considered thermally stable in atmospheric conditions. The reaction with air is covered under the subsection dealing with ignition probabilities.

4.1.2.4 Flammable and Combustible Components

Flammable and combustible components are those that can ignite and give a number of hazardous effects, depending on the nature of the component and conditions. These effects may include pool fires, jet fires and flash fires as well as explosions and fireballs.

The flammable and combustible components to be stored on, produced at or delivered to site, are listed in Table 4-1. These components have been analysed for fire and explosion risks.

Table 4-1: Flammable and combustible components to be stored on, produced at or delivered to site

Component	Flashpoint (°C)	Boiling Point (°C)	LFL (vol. %)	UFL (vol. %)
Natural gas (methane)	-188	-161	5	15
Diesel	> 55	290	0.6	7

4.1.3 Physical Properties

For this study, natural gas and diesel were modelled as a pure component, as given in Table 4-2. The physical properties used in the simulations were based on the DIPPR[1] data base, which are preloaded in the simulation software.

Table 4-2: Representative components

Component	Modelled as
Natural gas	Methane
Diesel	Dodecane

4.1.4 Components Excluded from the Study

Components excluded from the study, are listed in Table 4-3.

Table 4-3: Components excluded from the study

Component	Inventory	Reasons for Exclusion
Nitrogen	Portable cylinders	Will only be brought on site when maintenance would be required and would be in cylinders.
Lube oil	Small, used to lubricate the gensets	High flash point >100ºC.

1 Design Institute for Physical Properties

4.2 Physical and Consequence Modelling

In order to establish which impacts follow an accident, it is first necessary to estimate the physical process of the spill (i.e., rate and size), spreading of the spill, evaporation from the spill, subsequent atmospheric dispersion of the airborne cloud and, in the case of ignition, the burning rate and resulting thermal radiation from a fire and the overpressures from an explosion.

The second step is then to estimate the consequences of a release on humans, fauna, flora and structures in terms of the significance and extent of the impact in the event of a release. The consequences could be due to toxic or asphyxiant vapours, thermal radiation or explosion overpressures. They may be described in various formats.

The simplest methodology would show a comparison of predicted concentrations, thermal radiation or overpressures to short-term guideline values.

In a different but more realistic fashion, the consequences may be determined by using a dose-response analysis. Dose-response analysis aims to relate the intensity of the phenomenon that constitutes a hazard to the degree of injury or damage that it can cause. Probit analysis is possibly the method mostly used to estimate probability of death, hospitalisation or structural damage. The probit is a lognormal distribution and represents a measure of the percentage of the vulnerable resource that sustains injury or damage. The probability of injury or death (i.e., the risk level) is in turn estimated from this probit (risk characterisation).

Consequence modelling gives an indication of the extent of the impact for selected events and is used primarily for emergency planning. A consequence that would not cause irreversible injuries would be considered insignificant, and no further analysis would be required. The effects from major incidents are summarised in the following subsections.

4.2.1 Fires

Combustible and flammable components within their flammable limits may ignite and burn if exposed to an ignition source of sufficient energy. On process plants, releases with ignition normally occur as a result of a leakage or spillage. Depending on the physical properties of the component and the operating parameters, combustion may take on a number of forms, such as pool fires, jet fires, flash fires and so forth.

4.2.1.1 Thermal Radiation

The effect of thermal radiation is very dependent on the type of fire and duration of exposure. Certain codes, such as the American Petroleum Institute API 520 and API 2000 codes, suggest values for the maximum heat absorbed by vessels to facilitate adequate relief designs in order to prevent failure of the vessel. Other codes, such as API 510 and the British Standards BS 5980 code, give guidelines for the maximum thermal radiation intensity and act as a guide to equipment layout, as shown in Table 4-4.

The effect of thermal radiation on human health has been widely studied, relating injuries to the time and intensity of exposure.

Table 4-4: Thermal radiation guidelines (BS 5980 of 1990)

Thermal Radiation Intensity (kW/m^2)	Limit
1.5	Will cause no discomfort for long exposure.
2.1	Sufficient to cause pain if unable to reach cover within 40 seconds.
4.5	Sufficient to cause pain if unable to reach cover within 20 seconds.
12.5	Minimum energy required for piloted ignition of wood and melting of plastic tubing.
25	Minimum energy required to ignite wood at indefinitely long exposures.
37.5	Sufficient to cause serious damage to process equipment.

For pool fires, jet fires and flash fires CPR 18E (Purple Book; 1999) suggests the following thermal radiation levels be reported:

- 4 kW/m^2, the level that glass can withstand, preventing the fire entering a building, and that should be used for emergency planning;
- 10 kW/m^2, the level that represents the 1% fatality for 20 seconds of unprotected exposure and at which plastic and wood may start to burn, transferring the fire to other areas;
- 35 kW/m^2, the level at which spontaneous ignition of hair and clothing occurs, with an assumed 100% fatality, and at which initial damage to steel may occur.

4.2.1.2 Bund and Pool Fires

Pool fires, either tank or bund fires, consist of large volumes of a flammable liquid component burning in an open space at atmospheric pressure.

The flammable component will be consumed at the burning rate, depending on factors including prevailing winds. During combustion, heat will be released in the form of thermal radiation. Temperatures close to the flame centre will be high but will reduce rapidly to tolerable temperatures over a relatively short distance. Any building or persons close to the fire or within the intolerable zone, will experience burn damage with severity depending on the distance from the fire and time exposed to the heat of the fire.

In the event of a pool fire, the flames will tilt according to the wind speed and direction. The flame length and tilt angle affect the distance of thermal radiation generated.

4.2.1.3 Jet Fires

Jet fires occur when a flammable component which is released with a high exit velocity, ignites.

In process industries, this may be due to design (such as flares) or due to accidental releases. Ejection of a flammable component from a vessel, pipe or pipe flange may give rise to a jet fire and in some instances, the jet flame could have substantial ‘reach’.

In modelling jet fires from punctures, the release can be considered to be steady-state. For underground modelling, consequence model considers a vertical jet flame at ground level, with wind tilt created by the current wind velocity. Above ground pipelines are modelled as horizontal releases at the release height.

Depending on wind speed, the flame may tilt and impinge on other pipelines, equipment or structures. The thermal radiation from these fires may cause injury to people or damage equipment some distance away from the source of the flame.

4.2.1.4 Fireball

A fireball occurs with the immediate ignition of a large gas release forming a mushroom-shaped cap that is fed from below by the established part of the fire, lasts typically for up to 30 seconds (depending on pipeline diameter and initial pressure).

4.2.1.5 Flash Fires

A loss of containment of a flammable component may mix with air, forming a flammable mixture. The flammable cloud would be defined by the lower flammable limit (LFL) and the upper flammable limit (UFL). The extent of the flammable cloud would depend on the quantity of the released and mixed component, physical properties of the released component, wind speed and weather stability.

An ignition within a flammable cloud can result in an explosion if the front is propagated by pressure. If the front is propagated by heat, then the fire moves across the flammable cloud at the flame velocity and is called a flash fire. Flash fires are characterised by low overpressure, and injuries are caused by thermal radiation. The effects of overpressure due to an exploding cloud are covered in the subsection dealing with vapour cloud explosions (VCEs).

A flash fire would extend to the lower flammable limit; however, due to the formation of pockets, it could extend beyond this limit to the point defined as the ½ LFL. It is assumed that people within the flash fire would experience lethal injuries, while people outside of the flash fire would remain unharmed. The ½ LFL is used for emergency planning to evacuate people to a safe distance in the event of a release.

4.2.2 Explosions

The concentration of a flammable component would decrease from the point of release to below the lower explosive limits (LEL), at which concentration the component can no longer ignite. The sudden detonation of an explosive mass would cause overpressures that could result in injury or damage to property.

Such an explosion may give rise to any of the following effects:

- Blast damage;
- Thermal damage;
- Missile damage;
- Ground tremors;
- Crater formation;
- Personal injury.

Obviously, the nature of these effects depends on the pressure waves and the proximity to the actual explosion. Of concern in this investigation are the ‘far distance effects’, such as limited structural damage and the breakage of windows, rather than crater formations.

Table 4-5 and Table 4-6 give a more detailed summary of the damage produced by an explosion due to various overpressures.

CPR 18E (Purple Book; 1999) suggests the following overpressures be determined:

- 0.03 bar overpressure, corresponding to the critical overpressure causing windows to break;
- 0.1 bar overpressure, corresponding to 10% of the houses being severely damaged and a probability of death indoors equal to 0.025:
    - o No lethal effects are expected below 0.1 bar overpressure on unprotected people in the open;
- 0.3 bar overpressure, corresponding to structures being severely damaged and 100% fatality for unprotected people in the open;
- 0.7 bar overpressure, corresponding to an almost entire destruction of buildings.

Table 4-5: Summary of consequences of blast overpressure (Clancey 1972)

Pressure (Gauge)		Damage
Psi	kPa	
0.02	0.138	Annoying noise (137 dB), if of low frequency (10 – 15 Hz).
0.03	0.207	Occasional breaking of large glass windows already under strain.
0.04	0.276	Loud noise (143 dB); sonic boom glass failure.
0.1	0.69	Breakage of small under strain windows.
0.15	1.035	Typical pressure for glass failure.
0.3	2.07	'Safe distance' (probability 0.95; no serious damage beyond this value); missile limit; some damage to house ceilings; 10% window glass broken.
0.4	2.76	Limited minor structural damage.
0.5–1.0	3.45–6.9	Large and small windows usually shattered; occasional damage to window frames.
0.7	4.83	Minor damage to house structures.
1.0	6.9	Partial demolition of houses, made uninhabitable.
1.0–2.0	6.9–13.8	Corrugated asbestos shattered; corrugated steel or aluminium panels, fastenings fail, followed by buckling; wood panels (standard housing) fastenings fail, panels blown in.
1.3	8.97	Steel frame of clad building slightly distorted.
2.0	13.8	Partial collapse of walls and roofs of houses.
2.0–3.0	13.8–20.7	Concrete or cinderblock walls (not reinforced) shattered.
2.3	15.87	Lower limit of serious structural damage.
2.5	17.25	50% destruction of brickwork of house.
3.0	20.7	Heavy machines (1.4 t) in industrial building suffered little damage; steel frame building distorted and pulled away from foundations.
3.0–4.0	20.7–27.6	Frameless, self-framing steel panel building demolished.
4.0	27.6	Cladding of light industrial buildings demolished.
5.0	34.5	Wooden utilities poles (telegraph, etc.) snapped; tall hydraulic press (18 t) in building slightly damaged.
5.0–7.0	34.5–48.3	Nearly complete destruction of houses.
7.0	48.3	Loaded train wagons overturned.
7.0–8.0	48.3–55.2	Brick panels (20 – 30 cm) not reinforced fail by shearing or flexure.
9.0	62.1	Loaded train boxcars completely demolished.
10.0	69.0	Probable total destruction buildings; heavy (3 t) machine tools moved and badly damaged; very heavy (12 000 lb. / 5443 kg) machine tools survived.
300	2070	Limit of crater lip.

Table 4-6: Damage caused by overpressure effects of an explosion (Stephens 1970)

Equipment	Overpressure (psi)																								
	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	12	14	16	18	20
Control house steel roof	A	C	V				N																		
Control house concrete roof	A	E	P	D			N																		
Cooling tower	B			F			O																		
Tank: cone roof		D				K							U												
Instrument cubicle			A			LM						T													
Fire heater				G	I					T															
Reactor: chemical				A				I				P						T							
Filter				H					F									V			T				
Regenerator						I				IP					T										
Tank: floating roof						K							U												D
Reactor: cracking							I							I							T				
Pine supports							P					SO													
Utilities: gas meter									Q																
Utilities: electric transformer									H					I						T					
Electric motor										H								I							V
Blower										Q										T					
Fractionation column											R			T											
Pressure vessel horizontal												PI						T							
Utilities: gas regulator												I								MQ					
Extraction column													I							V	T				
Steam turbine															I						M	S			V
Heat exchanger															I			T							
Tank sphere																I						I	T		
Pressure vessel vertical																					I	T			
Pump																					I		Y		

A	Windows and gauges break
B	Louvers fall at 0.3–0.5 psi
C	Switchgear is damaged from roof collapse
D	Roof collapses
E	Instruments are damaged
F	Inner parts are damaged
G	Bracket cracks
H	Debris-missile damage occurs
I	Unit moves and pipes break
J	Bracing fails
K	Unit uplifts (half filled)
L	Power lines are severed
M	Controls are damaged
N	Block wall fails
O	Frame collapses
P	Frame deforms
Q	Case is damaged
R	Frame cracks
S	Piping breaks
T	Unit overturns or is destroyed
U	Unit uplifts (0.9 filled)
V	Unit moves on foundations

4.2.2.1 Vapour Cloud Explosions (VCEs)

The release of a flammable component into the atmosphere could result in formation of a flash fire, as described in the subsection on flash fires, or a vapour cloud explosion (VCE). In the case of a VCE, an ignited vapour cloud between the higher explosive limits (HEL) and the lower explosive limit (LEL) could form a fireball with overpressures that could result in injury or damage to property.

4.2.2.2 Boiling Liquid Expanding Vapour Explosions (BLEVEs)

A boiling liquid expanding vapour explosion (BLEVE) can occur when a flame impinges on a pressure cylinder, particularly in the vapour space region where cooling by evaporation of the contained material does not occur; the cylinder shell would weaken and rupture with a total loss of the contents, and the issuing mass of material would burn as a massive fireball.

The major consequences of a BLEVE are intense thermal radiation from the fireball, a blast wave and propelled fragments from the shattered vessel. These fragments may be projected to considerable distances. Analyses of the travel range of fragment missiles from a number of BLEVEs suggest that the majority land within 700 m from the incident. A blast wave from a BLEVE is fairly localised but can cause significant damage to immediate equipment.

A BLEVE occurs sometime after the vessel has been engulfed in flames. Should an incident occur that could result in a BLEVE, people should be evacuated to beyond the 1% fatality line.

4.3 Risk Analysis

4.3.1 Background

It is important to understand the difference between hazard and risk.

A hazard is anything that has the potential to cause damage to life, property and the environment. Furthermore, it has constant parameters (like those of petrol, chlorine, ammonia, etc.) that pose the same hazard wherever present.

On the other hand, risk is the probability that a hazard will actually cause damage and goes along with how severe that damage will be (consequence). Risk is therefore the probability that a hazard will manifest itself. For instance, the risks of a chemical accident or spill depends upon the amount present, the process the chemical is used in, the design and safety features of its container, the exposure, the prevailing environmental and weather conditions and so on.

Risk analysis consists of a judgement of probability based on local atmospheric conditions, generic failure rates and severity of consequences, based on the best available technological information.

Risks form an inherent part of modern life. Some risks are readily accepted on a day-to-day basis, while certain hazards attract headlines even when the risk is much smaller, particularly in the field of environmental protection and health. For instance, the risk of one-in-ten-thousand chance of death per year associated with driving a car is acceptable to most people, whereas the much lower risks associated with nuclear facilities (one-in-ten-million chance of death per year) are deemed unacceptable.

A report by the British Parliamentary Office of Science and Technology (POST), entitled 'Safety in Numbers? Risk Assessment and Environmental Protection', explains how public perception of risk is influenced by a number of factors in addition to the actual size of the risk. These factors were summarised as follows in Table 4-7.

Table 4-7: Influence of public perception of risk on acceptance of that risk, based on the POST report

Control	People are more willing to accept risks they impose upon themselves or they consider to be 'natural' than to have risks imposed upon them.
Dread and Scale of Impact	Fear is greatest where the consequences of a risk are likely to be catastrophic rather than spread over time.
Familiarity	People appear more willing to accept risks that are familiar rather than new risks.
Timing	Risks seem to be more acceptable if the consequences are immediate or short term, rather than if they are delayed (especially if they might affect future generations).
Social Amplification and Attenuation	Concern can be increased because of media coverage, graphic depiction of events or reduced by economic hardship.
Trust	A key factor is how far the public trusts regulators, policy makers or industry; if these bodies are open and accountable (being honest as well as admitting mistakes and limitations and taking account of differing views without disregarding them as emotive or irrational), then the public is more likely to consider them credible.

A risk assessment should be seen as an important component of ongoing preventative action, aimed at minimising or hopefully avoiding accidents. Reassessments of risks should therefore follow at regular intervals and after any changes that could alter the nature of the hazard, so contributing to an overall prevention programme and emergency response plan of the facility. Risks should be ranked with decreasing severity and the top risks reduced to acceptable levels.

Procedures for predictive hazard evaluation have been developed for the analysis of processes when evaluating very low probability accidents with very high consequences (for which there is little or no experience) as well as more likely releases with fewer consequences (for which there may be more information available). These address both the probability of an accident as well as the magnitude and nature of undesirable consequences of that accident. Risk is usually defined as some simple function of both the probability and consequence.

4.3.2 Predicted Risk

Physical and consequence modelling addresses the impact of a release of a hazardous component without taking into account probability of occurrence. This merely illustrates the significance and the extent of the impact in the event of a release. Modelling should also analyse cascading or knock-on effects due to incidents in the facility and the surrounding industries and suburbs.

During a risk analysis, the likelihood of various incidents is assessed, the consequences calculated and finally the risk for the facility is determined.

4.3.3 Generic Equipment Failure Scenarios

In order to characterise various failure events and assign a failure frequency, fault trees were constructed starting with a final event and working from the top down to define all initiating events and frequencies. Unless otherwise stated, analysis was completed using published failure rate data (RIVM 2009). Equipment failures can occur in tanks, pipelines and other items handling hazardous chemical components. These failures may result in:

- Release of combustible, flammable and explosive components with fires or explosions upon ignition.

4.3.3.1 Storage Vessels

Scenarios involving storage vessels can include catastrophic failures that would lead to leakage into the bund with a possible bund fire. A tank-roof failure could result in a possible tank-top fire. The fracture of a nozzle or transfer pipeline could also result in leakage into the bund.

Typical failure frequencies for atmospheric and pressure vessels are listed, respectively, in Table 4-8 and Table 4-9.

Table 4-8: Failure frequencies for atmospheric vessels

Event	Leak Frequency (per item per year)
Small leaks	$1x10^{-4}$
Severe leaks	$3x10^{-5}$
Catastrophic failure	$5x10^{-6}$

Table 4-9: Failure frequencies for pressure vessels

Event	Failure Frequency (per item per year)
Small leaks	$1x10^{-5}$
Severe leaks	$5x10^{-7}$
Catastrophic failure	$5x10^{-7}$

4.3.3.2 Transport and Process Piping

Piping may fail as a result of corrosion, erosion, mechanical impact damage, pressure surge (water hammer) or operation outside the design limitations for pressure and temperature. Failures caused by corrosion and erosion usually result in small leaks, which are easily detected and corrected quickly. For significant failures, the leak duration may be from 10–30 minutes before detection.

Generic data for leak frequency for process piping is generally expressed in terms of the cumulative total failure rate per year for a 10 m section of pipe for each pipe diameter. Furthermore, failure frequency normally decreases with increasing pipe diameter. Scenarios and failure frequencies for a pipeline apply to pipelines with connections, such as flanges, welds and valves.

The failure data given in Table 4-10 represents the total failure rate, incorporating all failures of whatever size and due to all probable causes. These frequencies are based on an assumed environment where no excessive vibration, corrosion, erosion or thermal cyclic stresses are expected. For incidents causing significant leaks (such as corrosion), the failure rate will be increased by a factor of 10.

Table 4-10: Failure frequencies for process pipes

Description	Frequencies of Loss of Containment for Process Pipes (per meter per year)	
	Full Bore Rupture	Leak
Nominal diameter < 75 mm	$1x10^{-6}$	$5x10^{-6}$
75 mm < nominal diameter < 150 mm	$3x10^{-7}$	$2x10^{-6}$
Nominal diameter > 150 mm	$1x10^{-7}$	$5x10^{-7}$

4.3.3.3 Pumps and Compressors

Pumps can be subdivided roughly into two different types, reciprocating pumps and centrifugal pumps. This latter category can be further subdivided into canned pumps (sealless pumps) and gasket (pumps with seals). A canned pump can be defined as an encapsulated pump where the process liquid is located in the space around the rotor (impeller), in which case gaskets are not used.

Compressors can also be subdivided roughly into reciprocating compressors and centrifugal compressors.

Failure rates for pumps and compressors, are given in Table 4-11 and Table 4-12.

Table 4-11: Failure frequency for centrifugal pumps and compressors

Event	Canned (No Gasket) Frequency (per annum)	Gasket Frequency (per annum)
Catastrophic failure	1.0×10^{-5}	1.0×10^{-4}
Leak (10% diameter)	5.0×10^{-5}	4.4×10^{-3}

Table 4-12: Failure frequency for reciprocating pumps and compressors

Event	Frequency (per annum)
Catastrophic failure	1.0×10^{-4}
Leak (10% diameter)	4.4×10^{-3}

4.3.3.4 Loading and Offloading

Loading can take place from a storage vessel to a transport unit (road tanker, tanker wagon or ship), or from a transport unit to a storage vessel. The failure frequencies for loading and offloading arms, are given in Table 4-13.

Table 4-13: Failure frequencies for loading and offloading arms and hoses

Event	Frequency (per hour)	
	Loading and Offloading Arms	Loading and Offloading Hoses
Rupture	3×10^{-8}	4×10^{-6}
Leak with effective diameter at 10% of nominal diameter to max. 50 mm	3×10^{-7}	4×10^{-5}

4.3.3.5 Human Failure

Human error and failure can occur during any life cycle or mode of operation of a facility. Human failure can be divided into the following categories:

- Human failure during design, construction and modification of the facility;
- Human failure during operation and maintenance;
- Human failure due to errors of management and administration.

Human failure during design, construction and modification is part of the generic failure given in this subsection. Human failure due to errors of organisation and management are influencing factors. Some of the types of tasks that have been evaluated for their rates of human failure are given in Table 4-14.

Table 4-14: Human failure rates of specific types of tasks (CPR 12E 2005; Red Book)

Tasks	Human Failure (events per year)
Totally unfamiliar, performed at speed with no real idea of likely consequences.	0.55
Failure to carry out rapid and complex actions to avoid serious incident such as an explosion.	0.5
Complex task requiring high level of comprehension and skill.	0.16
Failure to respond to audible alarm in control room within 10 minutes.	$1.0x10^{-1}$
Failure to respond to audible alarm in quiet control room by some more complex action such as going outside and selecting one correct value among many.	$1.0x10^{-2}$
Failure to respond to audible alarm in quiet control room by pressing a single button.	$1.0x10^{-3}$
Omission or incorrect execution of step in a familiar start-up routine.	$1.0x10^{-3}$
Completing a familiar, well-designed, highly-practiced, routine task occurring several times per hour, performed to highest possible standards by a highly-motivated, highly-trained and experienced person totally aware of implications of failures, with time to correct potential error but without the benefit of significant job aids.	$4.0x10^{-4}$

4.3.3.6 Ignition Probability of Flammable Gases and Liquids

Estimation of probability of an ignition is a key step in assessment of risk for installations where flammable liquids or gases are stored. There is a reasonable amount of data available relating to characteristics of ignition sources and effects of release type and location.

Probability of ignition for stationary installations, is given in Table 4-15 (along with classification of flammable substances in Table 4-16). These can be replaced with ignition probabilities related to surrounding activities. For example, probability of a fire from a flammable release at an open flame would increase to a value of 1.

Table 4-15: Probability of direct ignition for stationary installations (RIVM 2009)

Substance Category	Source-Term Continuous	Source-Term Instantaneous	Probability of Direct Ignition
Category 0 Average to high reactivity	< 10 kg/s 10 – 100 kg/s > 100 kg/s	< 1000 kg 1000 – 10 000 kg > 10 000 kg	0.2 0.5 0.7
Category 0 Low reactivity	< 10 kg/s 10 – 100 kg/s > 100 kg/s	< 1000 kg 1000 – 10 000 kg > 10 000 kg	0.02 0.04 0.09
Category 1	All flow rates	All quantities	0.065
Category 2	All flow rates	All quantities	0.0043[1]
Category 3 Category 4	All flow rates	All quantities	0

Table 4-16: Classification of flammable substances

Substance Category	Description	Limits
Category 0	Extremely flammable	Liquids, substances and preparations that have a flashpoint lower than 0°C and a boiling point (or the start of the boiling range) less than or equal to 35°C Gaseous substances and preparations that may ignite at normal temperature and pressure when exposed to air.
Category 1	Highly flammable	Liquids, substances and preparations that have a flashpoint of below 21°C.
Category 2	Flammable	Liquids, substances and preparations that have a flashpoint equal to 21°C and less than 55°C.
Category 3		Liquids, substances and preparations that have a flashpoint greater than 55°C and less than or equal to 100°C.
Category 4		Liquids, substances and preparations that have a flashpoint greater than 100°C.

1 This value is taken from the CPR 18E (Purple Book; 1999). RIVM (2009) gives the value of delayed ignition as zero. RISCOM (PTY) LTD believes the CPR 18E is more appropriate for warmer climates and is a conservative value.

4.4 Risk Criteria

4.4.1 Maximum Individual Risk Parameter

Standard individual risk parameters include: average individual risk; weighted individual risk; maximum individual risk; and, the fatal accident rate. The lattermost parameter is more applicable to occupational exposures.

Only the maximum individual risk (MIR) parameter will be used in this assessment. For this, parameter frequency of fatality is calculated for an individual who is presumed to be present at a specified location. This parameter (defined as the consequence of an event multiplied by the likelihood of the event) is not dependent on knowledge of populations at risk. So, it is an easier parameter to use in the predictive mode, than average individual risk or weighted individual risk. The unit of measure is the risk of fatality per person per year.

4.4.2 Acceptable Risks

The next step, after having characterised a risk and obtained a risk level, is to recommend whether the outcome is acceptable.

In contrast to the employees at a facility, who may be assumed to be healthy, the adopted exposure assessment applies to an average population group that also includes sensitive subpopulations. Sensitive subpopulation groups are those people that for reasons of age or medical condition have a greater than normal response to contaminants. Health guidelines and standards used to establish risk normally incorporate safety factors that address this group.

Among the most difficult tasks of risk characterisation is the definition of acceptable risk. In an attempt to account for risks in a manner similar to those used in everyday life, the UK Health and Safety Executive (HSE) developed the risk ALARP triangle. Applying the triangle involves deciding:

- Whether a risk is so high that something must be done about it;
- Whether the risk is or has been made so small that no further precautions are necessary;
- If a risk falls between these two states so that it has been reduced to levels as low as reasonably practicable (ALARP).

This is illustrated in Figure 4-1.

ALARP stands for ‘as low as reasonably practicable’. As used in the UK, it is the region between that which is intolerable, at $1x10^{-4}$ per year, and that which is broadly acceptable, at $1x10^{-6}$ per year. A further lower level of risk, at $3x10^{-7}$ per year, is applied to either vulnerable or very large populations for land-use planning.

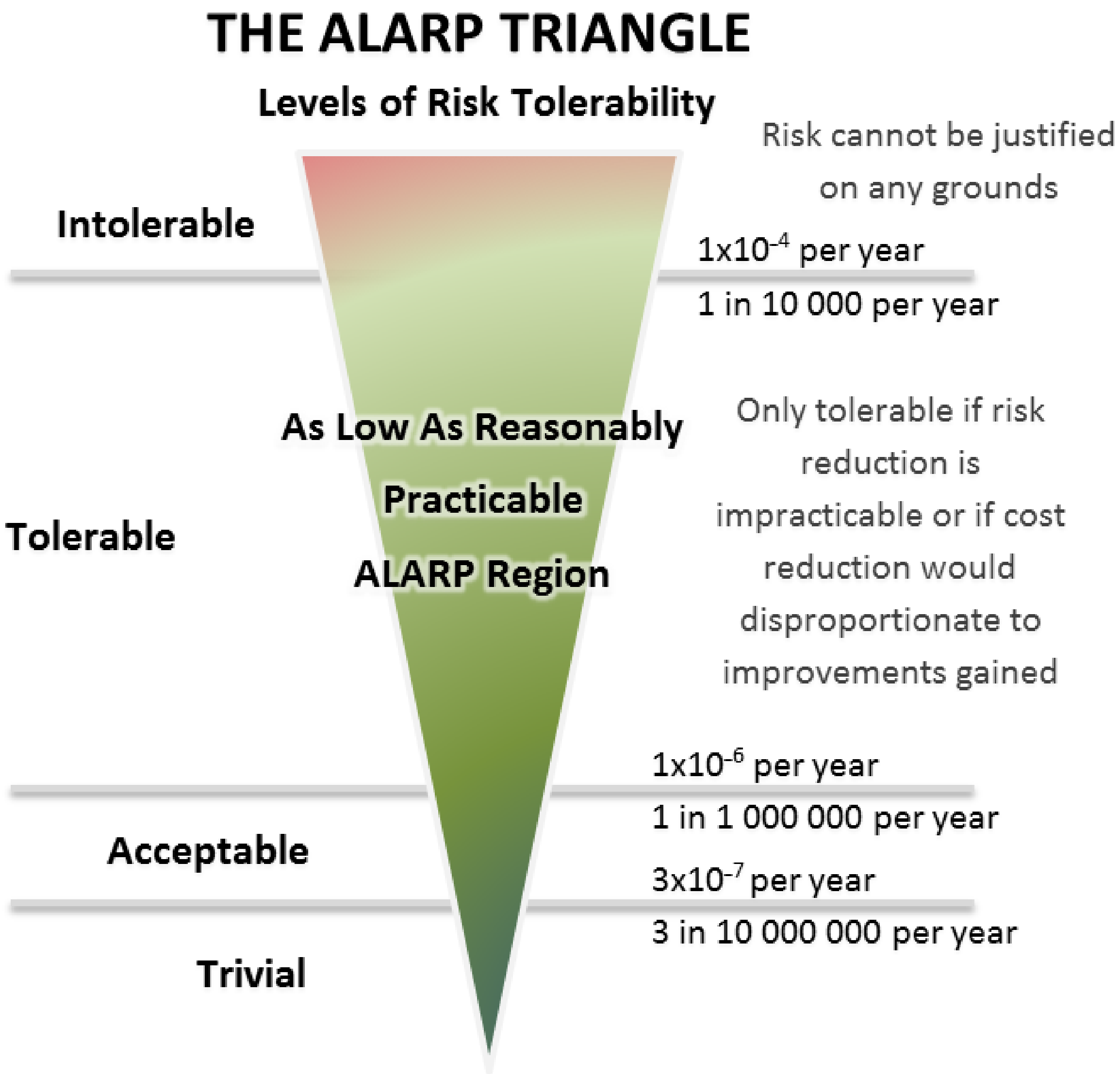


Figure 4-1: UK HSE decision-making framework

It should be emphasised that the risks considered acceptable to employees are different to those considered acceptable to the public. This is due to the fact that employees have personal protection equipment (PPE), are aware of the hazards, are sufficiently mobile to evade or escape the hazards and receive training in preventing injuries.

The HSE (UK) gives more detail on the word practicable in the following statement:

" *In essence, making sure a risk has been reduced to ALARP is about weighing the risk against the sacrifice needed to further reduce it. The decision is weighted in favour of health and safety because the presumption is that the duty-holder should implement the risk reduction measure. To avoid having to make this sacrifice, the duty-holder must be able to show that it would be grossly disproportionate to the benefits of risk reduction that would be achieved. Thus, the process is not one of balancing the costs and benefits of measures but, rather, of adopting measures except where they are ruled out because they involve grossly disproportionate sacrifices. Extreme examples might be:*

- *To spend £1m to prevent five staff members suffering bruised knees is obviously grossly disproportionate; but,*
- *To spend £1m to prevent a major explosion capable of killing 150 people is obviously proportionate.*

Proving ALARP means that if the risks are lower than $1x10^{-4}$ *fatalities per person per year, it can be demonstrated that there would be no more benefit from further mitigation, sometimes using cost benefit analysis.* *"*

4.4.3 Land Planning

SANS 1461 (2018) provides guidelines for land planning criteria. This standard is a requirement for completing the MHI risk assessment. Thus, the land planning criteria can only be applied after completion of the MHI risk assessment, under Section 9 of the MHI regulation.

In this study, RISCOM can only suggest land planning approvals, based on the information provided and would require governmental authorities to make final decisions, based on the MHI risk assessment that would be completed after final designs.

Land zoning applied in this study follows the SANS 1461 (2018) and HSE (UK) approach of defining the area affected into three zones, consistent to the ALARP approach (HSE 2011).

The three zones are defined as follows:

- The inner zone is enclosed by the risk of $1x10^{-5}$ fatalities per person per year isopleth;
- The middle zone is enclosed by the risk of $1x10^{-5}$ fatalities per person per year and the risk of $1x10^{-6}$ fatalities per person per year isopleths;
- The outer zone is enclosed by the risk $1x10^{-6}$ fatalities per person per year and the risk of $3x10^{-7}$ fatalities per person per year isopleths.

The risks decrease from the inner zone to the outer zone, as shown in Figure 4-2 and Figure 4-3.

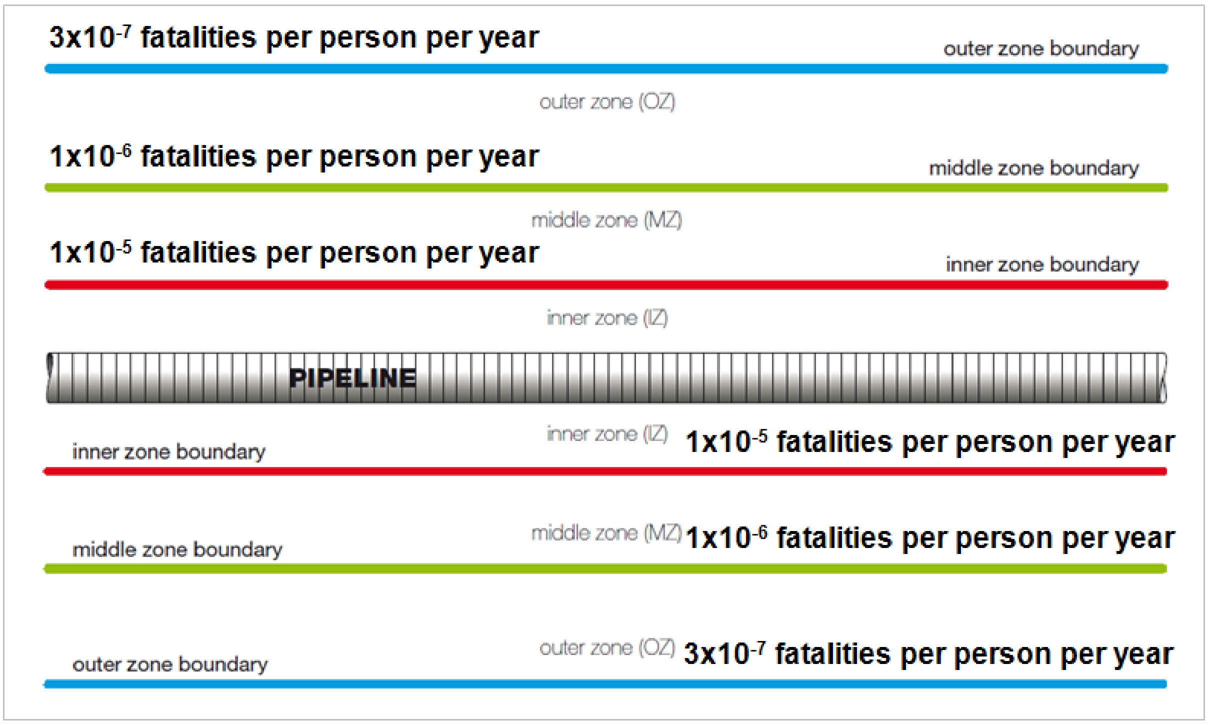


Figure 4-2: Town-planning zones for pipelines

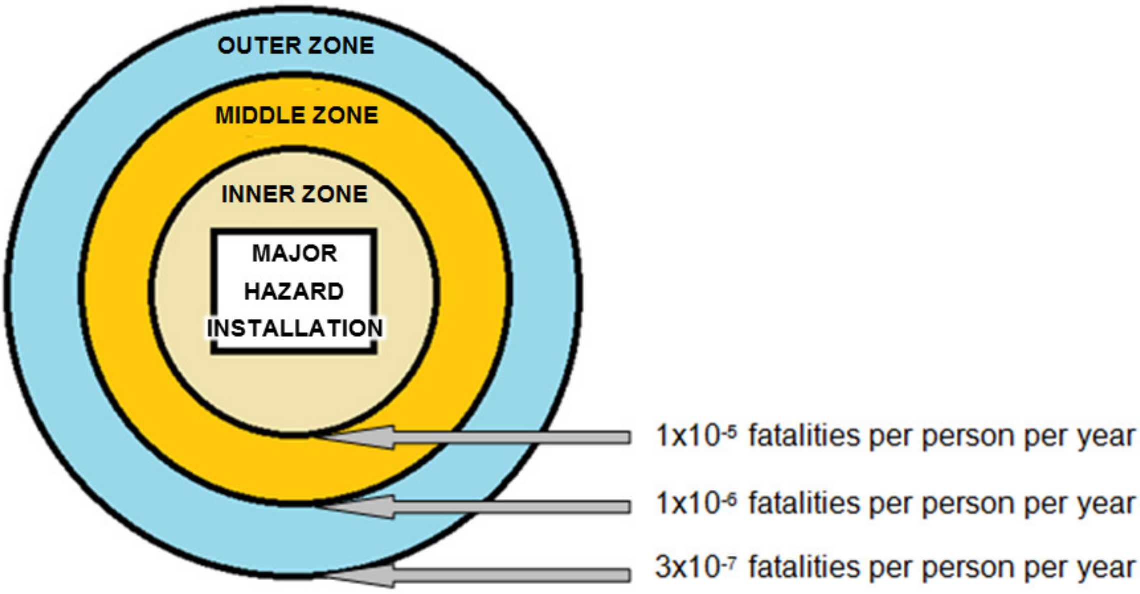


Figure 4-3: Town-planning zones

Once the zones are calculated, the HSE (UK) methodology then determines whether a development in a zone should be categorised as 'advised against' (AA) or as 'don't advise against' (DAA), depending on the sensitivity of the development, as indicated in Table 4-17. There are no land-planning restrictions beyond the outer zone.

Table 4-17: Land-use decision matrix

Level of Sensitivity	Development in Inner Zone	Development in Middle Zone	Development in Outer Zone
1	DAA	DAA	DAA
2	AA	DAA	DAA
3	AA	AA	DAA
4	AA	AA	AA

The sensitivity levels are based on a clear rationale: progressively more severe restrictions are to be imposed as the sensitivity of the proposed development increases.

There are four sensitivity levels, with the sensitivity for housing defined as follows:

- Level 1 is based on workers who have been advised of the hazards and are trained accordingly;
- Level 2 is based on the general public at home and involved in normal activities;
- Level 3 is based on the vulnerability of certain members of the public (e.g., children, those with mobility difficulties or those unable to recognise physical danger);
- Level 4 is based on large examples of Level 2 and of Level 3.

Refer to Appendix B for detailed planning advice for developments near hazardous installations (PADHI) tables. These tables illustrate how the HSE land-use decision matrix, generated using the three zones and the four sensitivity levels, is applied to a variety of development types.

4.4.4 Societal Risk Parameter

Risk criteria discussed so far have been for individual risks. There is also a need to consider incidents in the light of their effect on many people at the same time. Public response to an incident that may harm many people is thought to be worse than the response to many incidents causing the same number of individual deaths. Compliance with an individual risk criterion is necessary but not always sufficient. Even if it were sufficient, societal risk would also have to be examined in some circumstances.

Societal risk is risk of widespread or large-scale harm from a potential hazard. The implication is that consequence would be on such a scale as to provoke a major social or political response and may lead to public discussion about regulation in general. Societal risk therefore takes into account, the density of the population around a Major Hazard Installation site and is the probability in any one year (F) of an event affecting at least a certain number (N) of people (also known as an FN curve).

4.4.5 Scenario Selection

The standard used for the calculation was SANS 1461 (2018), which describes that cross-country pipeline must be done to IGEM/TD/2 and PD 8010-3. Furthermore, the SANS 1461 (2018) is based on RIVM (2009). The respective event trees represented below were taken from the respective standards. The cross-country pipeline was underground with a vertical release, while the process piping and plant were above ground with a horizontal release.

4.4.5.1 Scenarios for Release of a Pressurised Liquefied Gas

The nature of the release of a liquefied gas from a pressurised vessel is dependent on the position of the hole.

A hole above the liquid level will result in a vapour release only, and the release rate would be related to the size of the hole and internal pressure of the tank. Over a period of time, bulk temperature reduces, with an associated decrease in the vapour release rate.

A hole below the liquid level will result in a release of a liquid stream. In the reduced pressure of the atmosphere, a portion of the liquid will vaporise at the normal boiling point. This phenomenon is called flashing and is shown in Figure 4-4. The pool, formed after flashing, then evaporates at a rate proportional to the pool area, surrounding temperature and wind velocity.

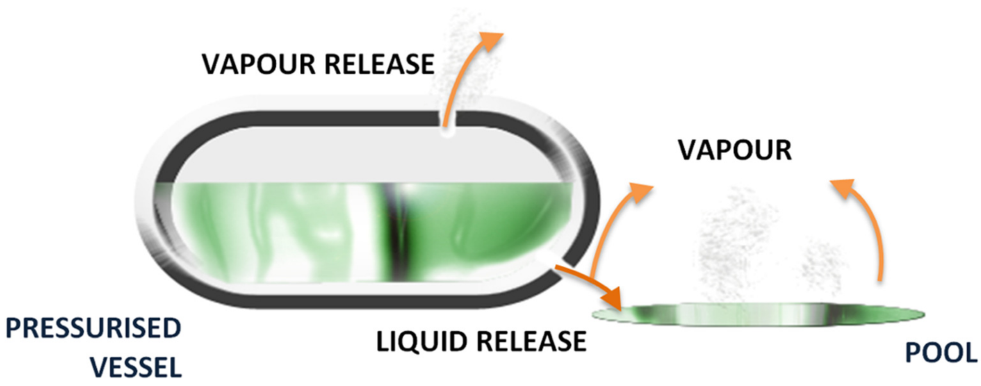


Figure 4-4: Airborne vapours from a loss of containment of liquefied gas stored in a pressurised vessel

4.4.5.2 Instantaneous Release of a Pressured Liquefied Flammable Gas

An instantaneous loss of containment of a liquefied flammable gas could result in the consequences given in the event tree of Figure 4-5. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

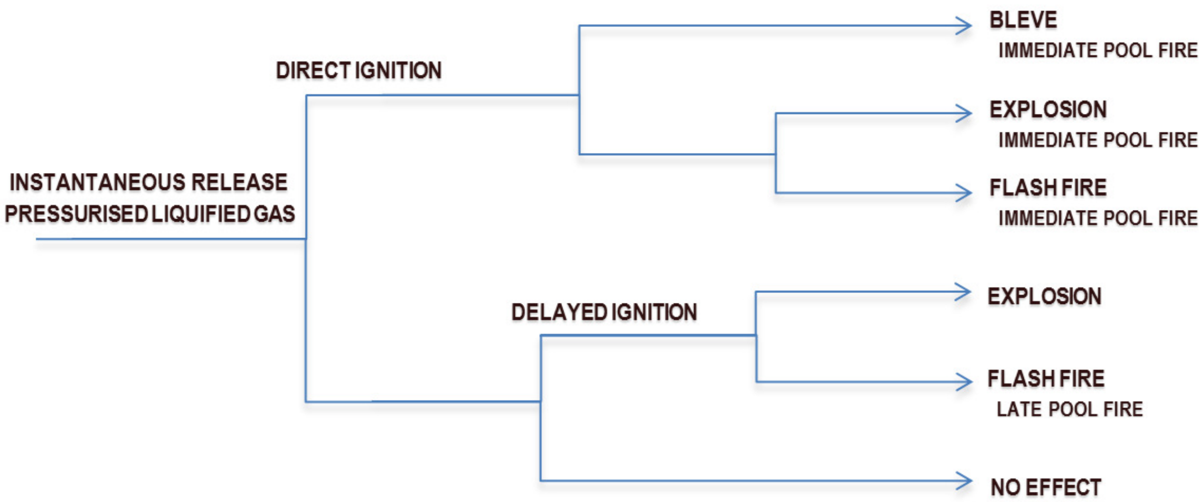


Figure 4-5: Event tree for an instantaneous release of a liquefied flammable gas

4.4.5.3 Continuous Release of a Pressurised Liquefied Flammable Gas

The continuous loss of containment of a liquefied flammable gas could result in the consequences given in the event tree of Figure 4-6. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

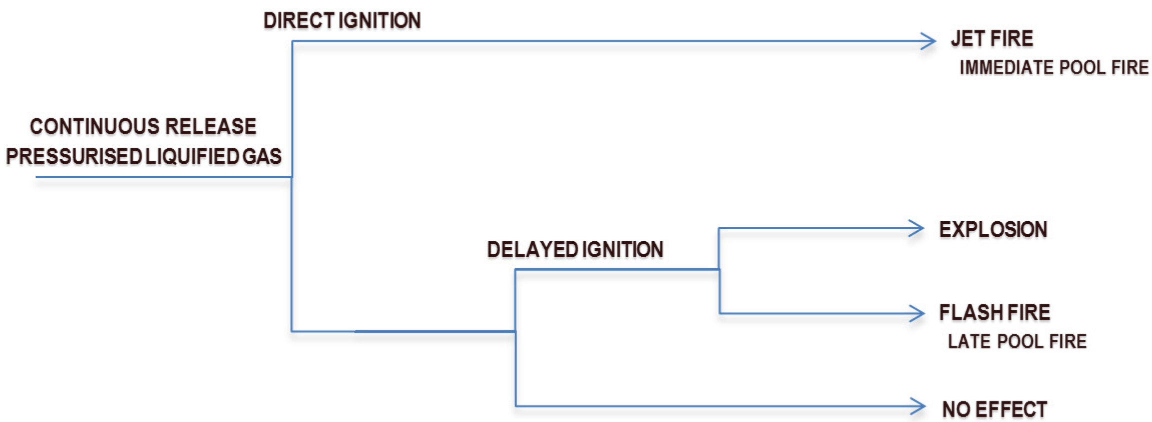


Figure 4-6: Event tree for a continuous release of a liquefied flammable gas

4.4.5.4 Continuous Release of a Flammable Gas

The continuous loss of containment of a flammable gas could result in the consequences given in the event tree of Figure 4-7. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

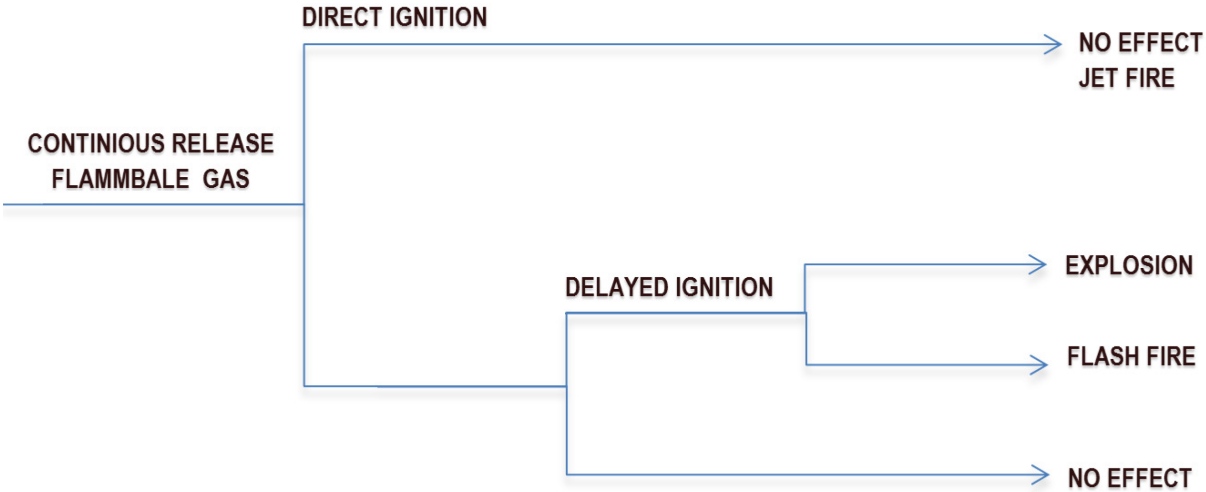


Figure 4-7: Event tree for a continuous release of a flammable gas

4.4.5.5 Continuous Release of a Flammable Liquid

The continuous loss of containment of a flammable liquid could result in the consequences given in the event tree of Figure 4-8. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

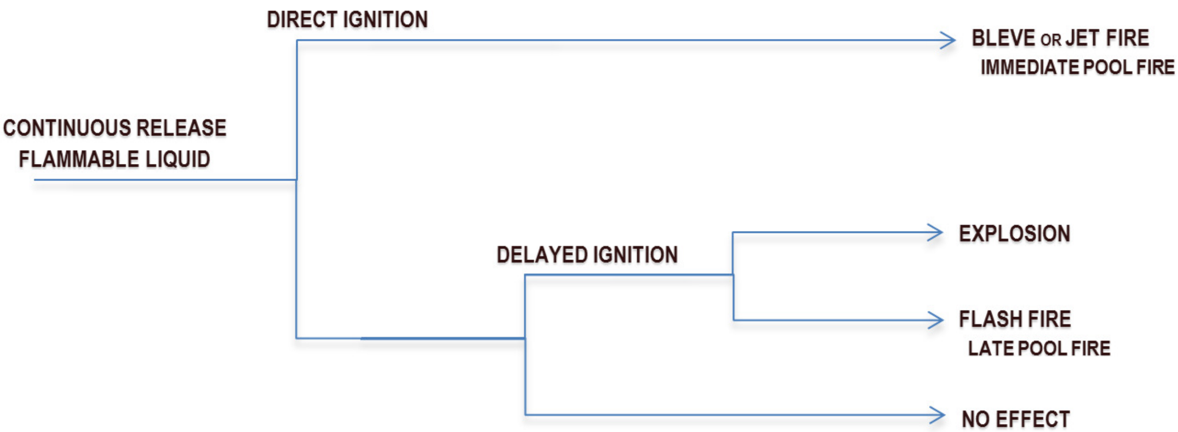


Figure 4-8: Event tree for a continuous release of a flammable liquid

5 RISK ASSESSMENT

Risk assessment was done of each processing unit by firstly selecting a scenario and then completing consequence and outflow modelling. Consequences with possible impacts beyond the site boundary were retained for risk analysis of the unit.

Finally, the risk of the entire facility is determined as a combination of the risk calculated for each unit.

5.1 Natural Gas Pipeline

5.1.1 The Purpose of the Processing Unit

The natural pipeline will tie into the main natural gas pipeline and end at the gas turbines. The process details at the incoming pipeline have not been established, nor the routing from the tie-in point to the gas turbines. For this study, the supply pressure was taken at 60 bar(g) at a temperature of 0ºC. The pipeline was assumed to be above ground with releases in the horizontal plane.

5.1.2 Hazardous Components

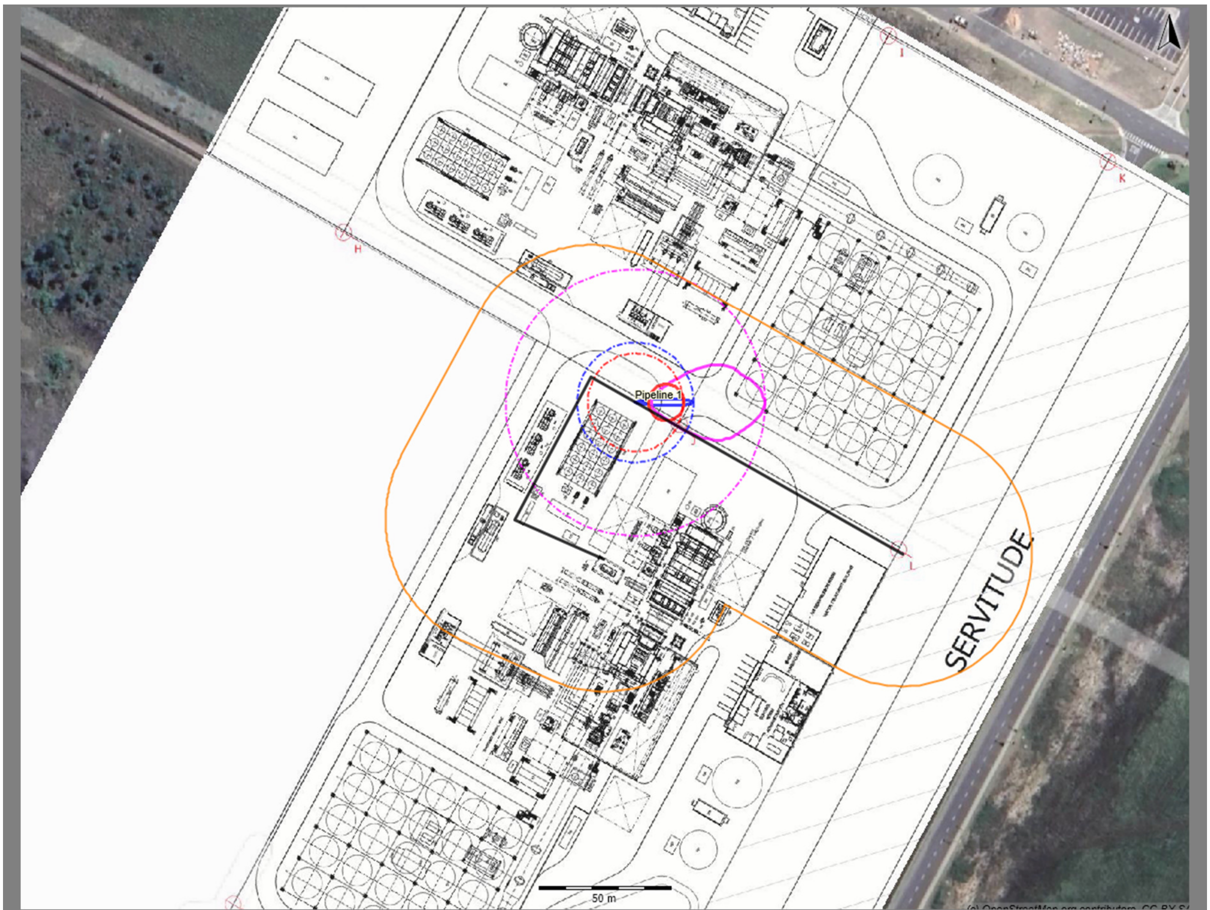
Natural gas is a flammable substance with fire and explosion hazards, as described in Section 4.1.2.1.

.

5.1.3 Consequence Modelling

A loss of containment from a full-bore rupture could result in flash fires, vapour cloud explosions or jet fires. All of these scenarios are shown in Figure 5-1, to the 1% fatality as a single loss of containment point. The solid lines indicate a release in a single direction, while the dashed lines indicate the extent form all wind directions. The orange line indicates the extent to the 1% fatality for the length of the pipeline to the southern gas turbine.

The scenario controlling the extent of the 1% fatality is the Jet Fire and could extend beyond the site boundaries, impacting neighbour, but would not extend beyond the RBIDZ 1F site boundary.



LEGEND	SCENARIO
(pink line)	Jet fire
(blue line)	Flash fire
(red line)	VCE
(orange line)	1% along the pipeline

Figure 5-1: 1% Fatality along the pipeline routing

5.2 Hydrogen Storage

5.2.1 The Purpose of the Processing Unit

Hydrogen will be delivered to site in hydrogen trailers. The trailer is assured to be that of a standard hydrogen trailer of 190 kg hydrogen inventory with a storage pressure at 225 bar(g).

5.2.2 Hazardous Components

Hydrogen is a flammable gas with fires and explosion potential and discussed in Section 4.1.2.1.

Most importantly, hydrogen produces an invisible flame.

5.2.3 Consequence Modelling

The scenarios modelled for the hydrogen trailer, are listed in Table 5-1.

Table 5-1: Scenarios modelled for the hydrogen trailer

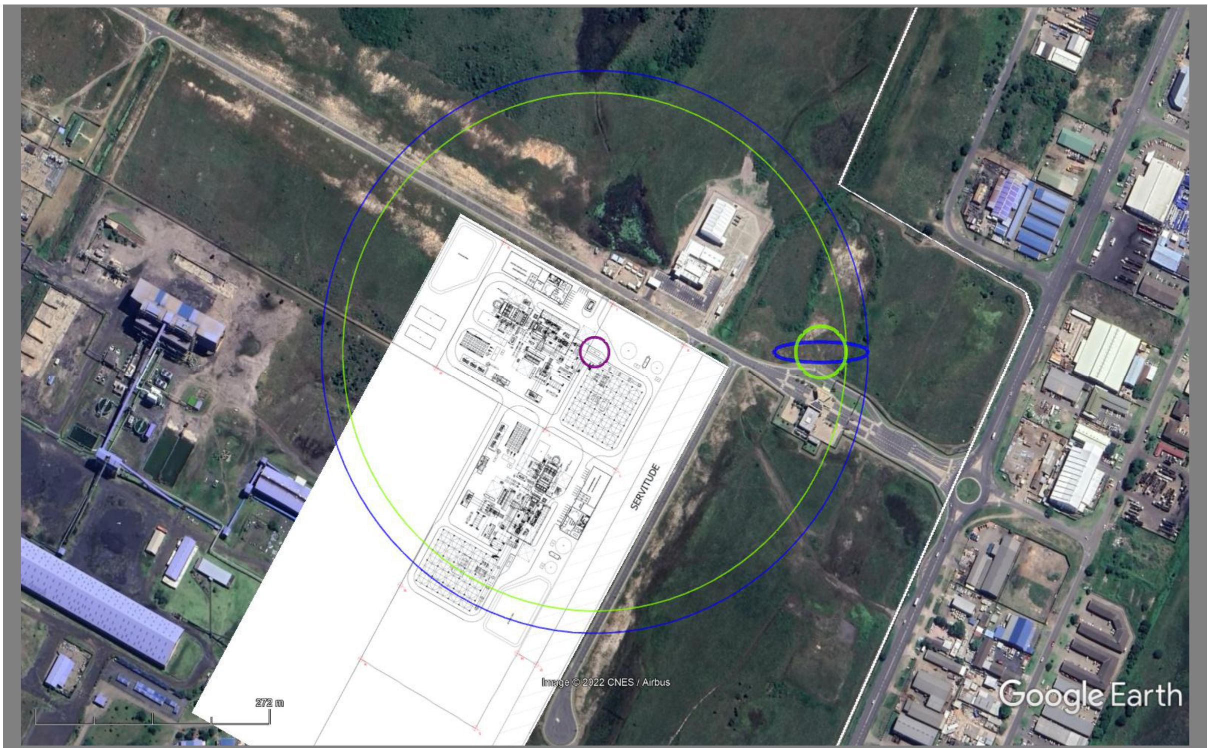
Hydrogen trailer	• Catastrophic failure • 10 Minute release • 10 mm Hole	• Jet fires • Flash fires. • Vapour cloud explosions • BLEVE

5.2.4 Consequence Modelling

The loss of containment of hydrogen could result in fires and explosions. The maximum distance to the 1% fatality would be the catastrophic failure of the hydrogen trailer at a low wind speed.

The maximum extent to the 1% fatality from a catastrophic loss of containment, is shown in Figure 5-2. The thicker lines indicated the extent from a westerly wind, while the thinner lines indicate the extent from all wind directions.

The extent of the 1% fatality could reach the main entrance and could impact neighbouring sites, but would generally not extend beyond the RBIDZ 1F site boundary.



LEGEND	SCENARIO / DISTANCE (m)
(purple line)	Fireball / 33
(blue line)	Flash fire / 371
(green line)	Vapour cloud explosion / 292

Figure 5-2: The extent to the 1% fatality from the worst-case loss of containment of the hydrogen trailer at the northern gas turbine

5.3 Ammonia

Ammonia will be used to adjust the pH of the boiler water feed. The ammonia system has not been fully specified. For this study, ammonia was assumed to be stored in a 60 m^3 cryogenic storage tank.

5.3.1 Hazardous Components

Ammonia is a highly toxic substance. The properties of ammonia are discussed in Section 4.1.2.1.

5.3.2 Consequence Modelling

The scenarios modelled for the ammonia transport pipeline and storage, are listed in Table 5-2.

Table 5-2: Scenarios modelled for the ammonia transport pipeline and storage

Ammonia tank	• Catastrophic failure • 10 Minute release • 10 mm Hole	Asphyxiation	• 60 m^3 Cryogenic storage tank
Ammonia tanker	• Tanker failure • Hose failure • Hose leak	Asphyxiation	• 20 m^3 tanker • Delivery twice per week

5.3.2.1 Toxic Vapour Clouds

Ammonia is a highly toxic component and could result in fatalities associated with a loss of containment.

ERPG-3 is the maximum air concentration below, which it is believed that nearly all individuals could be exposed without experiencing or developing life-threatening health effects. The ERPG-2 concentration is the maximum air concentration below, which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or serious health effects or symptoms that could impair an individual's ability to take protective action. The ERPG-2 is used for emergency planning to indicate the furthest downwind distance to evacuation of nearby populations in the event of a release.

Figure 5-3 illustrates the ERPG-2 endpoint distances for various release scenarios in worst-case meteorological conditions. The ERPG-2 for the worst case (release of contents in 10 minutes) would extend 9 km downwind under a low wind speed condition (1.5 $m.s^{-1}$).

The thick lines indicate the shape of the plume from a westerly wind direction, while the thinner lines indicate the extent of the plume from all directions. The westerly wind direction used does not indicate the predominant wind, but is used for illustrative purposes only.

LEGEND	SCENARIO
(cyan line)	60 m^3 Storage vessel: Catastrophic failure
(yellow line)	60 m^3 Storage vessel: Release in 10 minutes

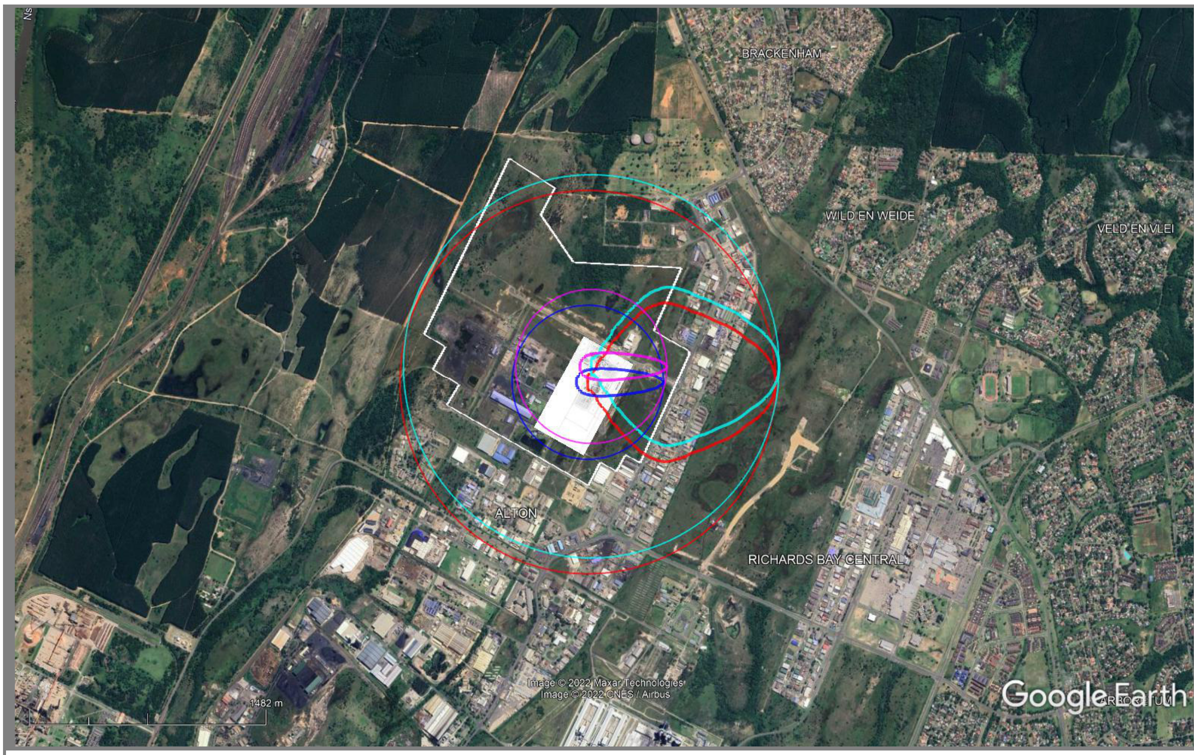
N

Figure 5-3: The extent of the ERPG-2 values of ammonia following a large release

The ERPG values give an indication of health effects from a one-hour exposure, but do not give an indication of probability of fatality. The 1% fatality represents the endpoint for these risk assessment calculations. Furthermore, the 1% fatality gives an indication of the extent of public liability in the event of a large release.

Figure 5-4 shows the scenarios with the largest distances to the 1% fatality, the furthest of which could extend 1176 m downwind. The thick line indicates the cloud plume from a westerly wind direction, while the thinner line represents the extent of the plume from all wind directions.

The 1% fatality could significantly impact neighbouring sites and could extend beyond the RBIDZ 1F site boundary, but would not reach residential areas.



LEGEND	SCENARIO
Magenta line	60 m^3 Storage vessel: Catastrophic failure (Gas turbine – North)
Cyan line	60 m^3 Storage vessel: Release in 10 minutes (Gas turbine – North)
Blue line	60 m^3 Storage vessel: Catastrophic failure (Gas turbine –South)
Red line	60 m^3 Storage vessel: Release in 10 minutes (Gas turbine – South)

Figure 5-4: Maximum extent of the 1% fatality for major releases

5.3.2.2 Summary of Impacts

Maximum distances from the point of release to the 1% fatality, are summarised for each scenario in Table 5-3.

Table 5-3: Maximum distance to 1% fatality from the point of release

Scenarios	Max. Distance to 1% Fatality (m)
Ammonia Road Tanker	
NH_3 Road tanker - Catastrophic failure	849
NH_3 Road tanker - Failure largest nozzle	633
NH_3 Road tanker - Failure offloading hose	633
NH_3 Road tanker - Leak offloading hose	82
Ammonia Tank	
Ammonia Tank - Catastrophic failure	897
Ammonia Tank - Fixed duration	1176
Ammonia Tank -10 mm hole	255
Ammonia Tank - pump failure	556

5.5 Diesel Storage and Offloading

5.5.1 The Purpose of the Processing Unit

Diesel will be used for back-up generators.

As the detail engineering designs have not been completed, a number of assumptions were made regarding the designs. The following was assumed in the modelling:

- 1 x 80 m^3 atmospheric storage tank;
- 100 m^2 bund size;
- Road tanker size 20 m^2;
- Delivery of 1 tanker per month;
- Tanker spillage limited to 250 m^2, due to the natural barriers on the road.

5.5.2 Hazardous Components

Diesel is considered combustible and will sustain combustion when lit. It is not considered toxic. The hazards of Diesel are described in more detail in Section 4.1.2.1.

5.5.3 Consequence Modelling

The scenarios modelled for the diesel transport pipeline, pumps and storage, are listed in Table 5-4.

Table 5-4: Scenarios modelled for the diesel transport pipeline, pumps and storage

Containment System	Causes	Potential Consequences	Comments
Diesel storage tank	• Catastrophic failure • Serious release into bund	• Pool fire	• Located within a bunded area • Overfill protection on the tanks
Diesel tanker	• Tanker failure • Hose failure • Hose leak	• Pool fire	• Secondary containment • Limited time on site
Pumps	• Tank failure	• Pool fire	• Located within a bunded area

5.5.3.1 Diesel Storage Tank

Diesel offloaded from the road tanker is transferred to the 50 kℓ storage tank. A loss of containment of the storage tank can be the due to a vessel / pipeline failure or overfilling.

An Instantaneous (catastrophic) failure of a storage tank can result in a proportion of the component overflowing the top of the bund, referred to as 'overtopping'. For the scenario of an instantaneous release, the amount of overtopping is taken to be an average of 33%. This is translated to the risk assessment by increasing the surface area of the bund by 50% (RIVM 2009) and would represent the worst-case scenario for the tank installation.

A tank leak, overfilling or piping failure (severe leak) would not result in overtopping, and even in the worst case, the spilt material would be contained within the bunded area.

The maximum effect of a pool fire from a loss of containment (catastrophic failure of the tank) in the storage area, is shown Figure 5-5. The isopleth represents the worst-case radiation at a high wind speed (9 m/s) and shows the maximum impact distance expected. The solid lines indicate the extent of the fire from a westerly wind, while the dashed lines indicate the maximum extent from all wind directions.

The 1% fatality or 10 kW/m^2 should remain within the site boundary, provided the diesel tank is not located near a site boundary.

The solid line represents the extent of the 1% fatality high velocity westerly winds, while the dashed line indicates the maximum extent from winds in all directions. The 10 kW/m^2 representing the 1% fatality, would remain within the RBIDZ 1F site boundary.

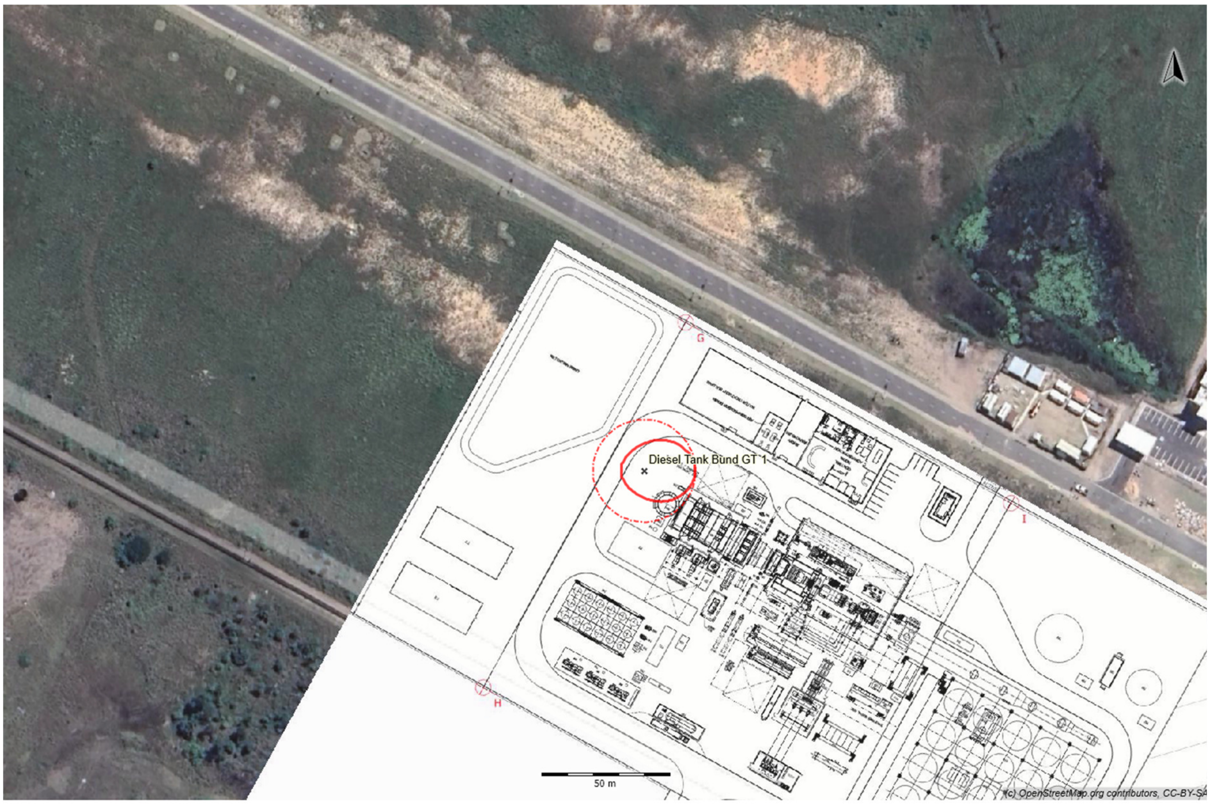


Figure 5-5: Thermal radiation from large diesel pool fires at the assumed position at the Northern gas turbine area

5.5.3.2 Diesel Offloading

A loss of containment of diesel would result from a failure of the offloading hose of the delivery tanker.

The maximum effect of pool fires, is shown in Figure 5-6. In this instance, the spilt material was calculated as the loss of containment from one 5 000 ℓ compartment and was assumed to spread evenly to a maximum area of the secondary containment of 250 m^2 RIVM (2009). The pool would shrink as the fuel is consumed during the fire.

The 1% fatality or 10 kW/m^2 should remain within the site boundary, provided the diesel tank is not located near a site boundary.

The solid line represents the extent of the 1% fatality high velocity westerly winds, while the dashed line indicates the maximum extent from winds in all directions. The 10 kW/m^2 representing the 1% fatality, should remain within the would remain within the RBIDZ 1F site boundary.

Figure 5-6: Thermal radiation from large diesel pool fires at the road offloading area at the assumed position at the Northern gas turbine area

5.5.3.3 Summary of Impacts

Maximum distances from the point of release to the 1% fatality, are summarised for each scenario in Table 5-5.

Table 5-5: Maximum distance to 1% fatality from the point of release

Scenarios	Max. Distance to 1% Fatality (m)
Diesel Tank Bund	
Diesel tank - Overfill	17
Diesel tank - Severe leak Set	17
Diesel tank - Catastrophic failure	20
Diesel Tanker Offloading	
Diesel tanker - Hose failure	13
Diesel tanker - Hose leak	29
Diesel tanker - Failure	25

5.6 Nitrogen

Nitrogen will be used to purge flammable lines and equipment. The nitrogen system has not been fully specified. For this study, nitrogen was assumed to be stored in a 30 m^3 cryogenic storage tank.

5.6.1 Hazardous Components

Nitrogen is not flammable or toxic, but can replace oxygen and will add as an asphyxiant. The properties of nitrogen are discussed in Section 4.1.2.1.

5.6.2 Consequence Modelling

The scenarios modelled for the nitrogen transport pipeline and storage, are listed in Table 5-6.

Table 5-6: Scenarios modelled for the nitrogen transport pipeline and storage

Nitrogen tank	• Catastrophic failure • 10 Minute release • 10 mm Hole	Asphyxiation	• 30 m^3 Cryogenic storage tank
Nitrogen tanker	• Tanker failure • Hose failure • Hose leak	Asphyxiation	• 45 m^3 tanker • Delivery twice per week

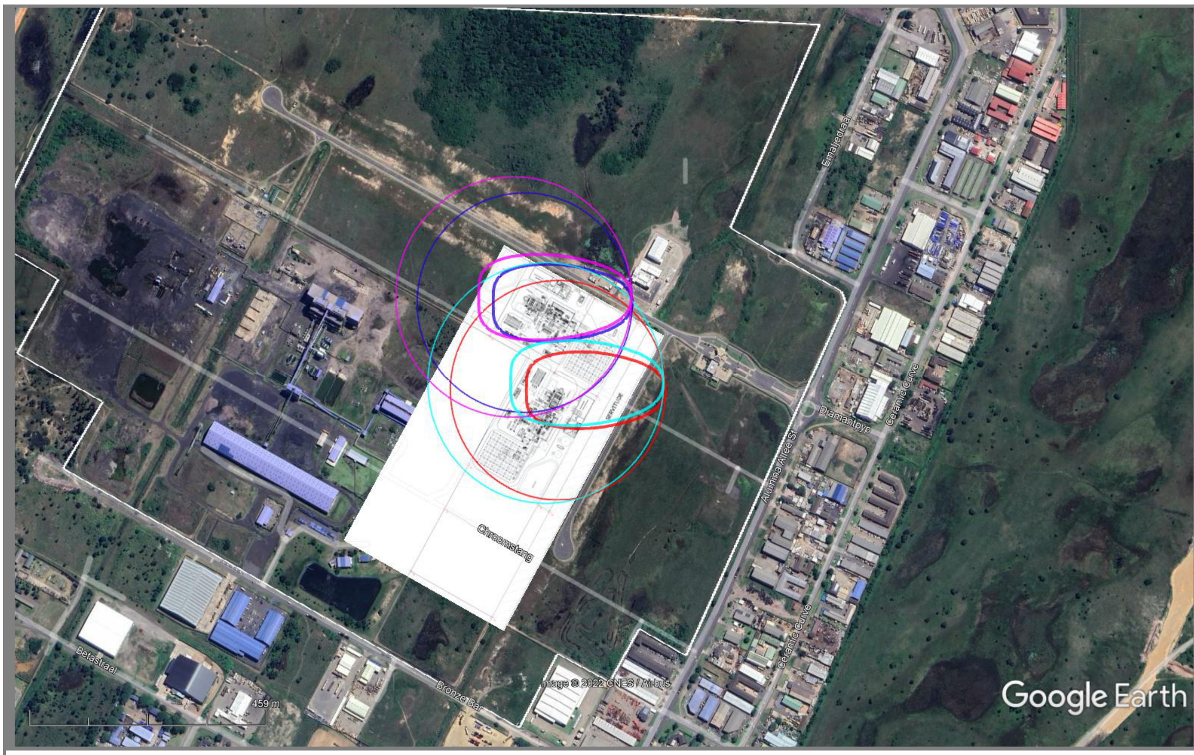
5.6.2.1 Toxic Vapour Clouds

Nitrogen is not considered to be a toxic component, but may displace oxygen resulting in asphyxiation. It is analysed in a manner similar to toxic components.

ERPG-3 is the maximum air concentration below, which it is believed that nearly all individuals could be exposed without experiencing or developing life-threatening health effects. The ERPG-2 concentration is the maximum air concentration below, which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or serious health effects or symptoms that could impair an individual's ability to take protective action. The ERPG-2 is used for emergency planning to indicate the furthest downwind distance to evacuation of nearby populations in the event of a release.

Figure 5-7 illustrates the ERPG-2 endpoint distances for various release scenarios in worst-case meteorological conditions. The ERPG-2 for the worst case (catastrophic failure of the storage vessel) would extend 209 m downwind under high wind speed conditions (9 m.s^{-1}).

The thick lines indicate the shape of the plume from a westerly wind direction, while the thinner lines indicate the extent of the plume from all directions. The westerly wind direction used does not indicate the predominant wind, but is used for illustrative purposes only.



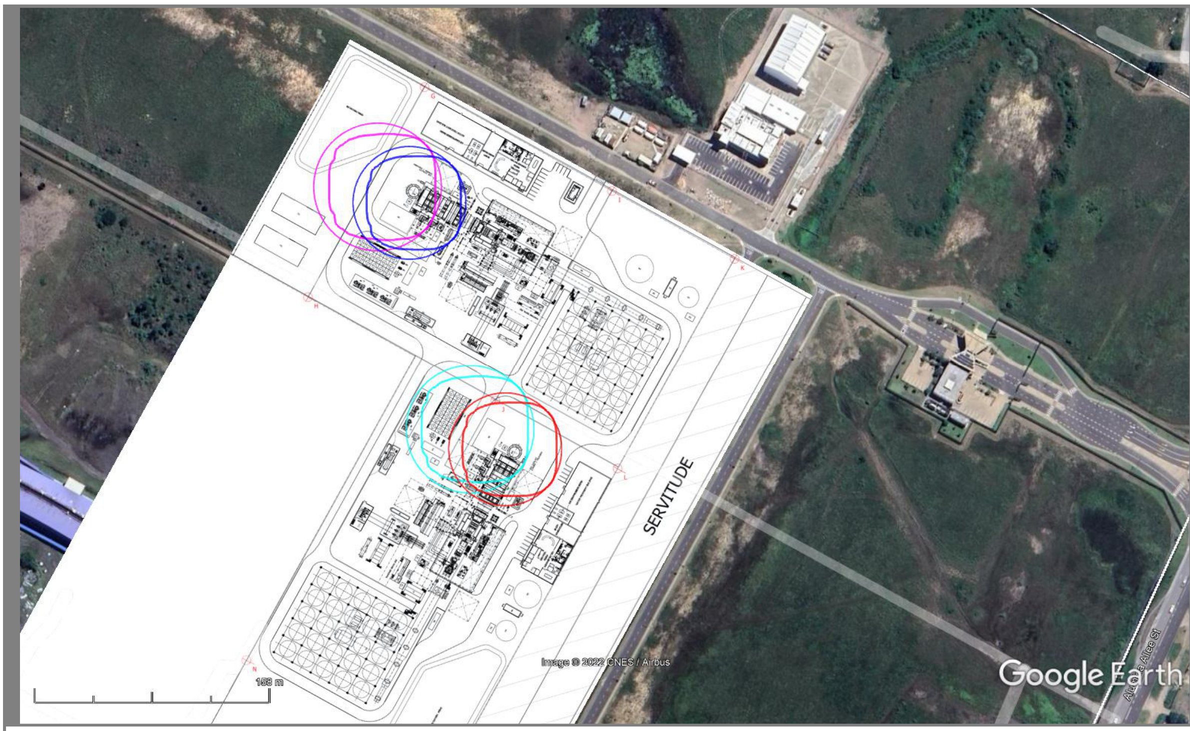
LEGEND	SCENARIO
(magenta)	Tanker: Catastrophic failure (Gas turbine – North)
(cyan)	Tanker: Catastrophic failure (Gas turbine – South)
(blue)	30 m^3 Storage vessel: Catastrophic failure (Gas turbine – North)
(red)	30 m^3 Storage vessel: Catastrophic failure (Gas turbine – South)

Figure 5-7: The extent of the ERPG-2 values of nitrogen following a large release, using the ERPG-2 value (832 000 ppm)

The ERPG values give an indication of health effects from a one-hour exposure, but do not give an indication of probability of fatality. The 1% fatality represents the endpoint for these risk assessment calculations. Furthermore, the 1% fatality gives an indication of the extent of public liability in the event of a large release.

Figure 5-8 shows the scenarios with the largest distances to the 1% fatality, the furthest of which could extend 39 m downwind. The thick line indicates the cloud plume from a westerly wind direction, while the thinner line represents the extent of the plume from all wind directions.

The 1% fatality should not significantly impact neighbouring sites and would only extend slightly beyond the RBIDZ 1F site boundary.



LEGEND	SCENARIO
Magenta line	Tanker: Catastrophic failure (Gas turbine – North)
Cyan line	Tanker: Catastrophic failure (Gas turbine – South)
Blue line	30 m^3 Storage vessel: Catastrophic failure (Gas turbine – North)
Red line	30 m^3 Storage vessel: Catastrophic failure (Gas turbine – South)

Figure 5-8: Maximum extent of the 1% fatality for major releases

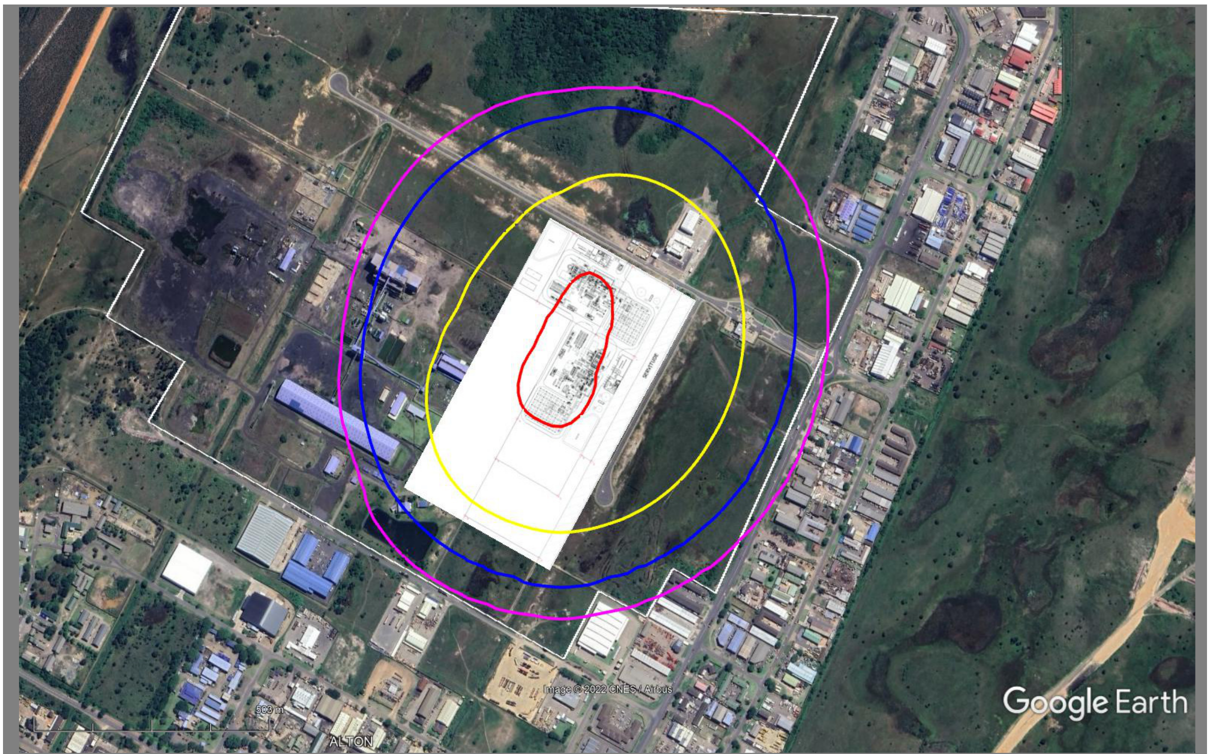
5.7 Combined Site Risk

The combined site risks are the summation of all risks posed by the site onto works or the public. These are represented as Maximum Individual Risks or Societal Risks, as described in Section 4.4.

5.7.1 Maximum Individual Risk

The combined site risk is the summation of all the individual risks, and is shown in Figure 5-9.

The risk of $1x10^{-6}$ fatalities per person per year isopleths extends beyond the site boundary and that alone **would be classified as a Major Hazard Installation** based on the risk posed.



LEGEND **RISK (fatalities per person per year)**

- Red: $1x10^{-4}$
- Yellow: $1x10^{-5}$
- Blue: $1x10^{-6}$
- Magenta: $3x10^{-7}$

N

Figure 5-9: Lethal probability isopleths associated with the proposed PRBGP3 facility in Richards Bay

Risks greater than $1x10^{-3}$ fatalities per person per year, for workers would be considered excessive. These risks would remain onsite and associated with the offloading operation.

Risks greater than $1x10^{-4}$ fatalities per person per year, considered tolerable for industrial areas but excessive for residential areas, extends beyond the proposed PRBGP3 site to the south.

The risk of $3x10^{-7}$ fatalities per person per year isopleth indicates the extent for land-use that would be suitable for vulnerable populations, such as hospitals, retirement homes, nursery schools, prisons, large gatherings in the open, and so forth. No such populations would be located within this area, indicating the acceptability of the location.

No new land planning should be approved without consultation of the PADHI land-planning tables attached in Appendix B and confirmed from the MHI risk assessment.

6 RISK TREATMENT / REDUCTION

From the simulations performed, the areas of highest risk have been identified as the release of ammonia, concluding that the risks to the public and workers would be considered excessive and would require mitigation for acceptance of the project, under the MHI regulations.

Mitigations that may be considered, but not limited to reduce risks to acceptable levels are listed in the following subsections.

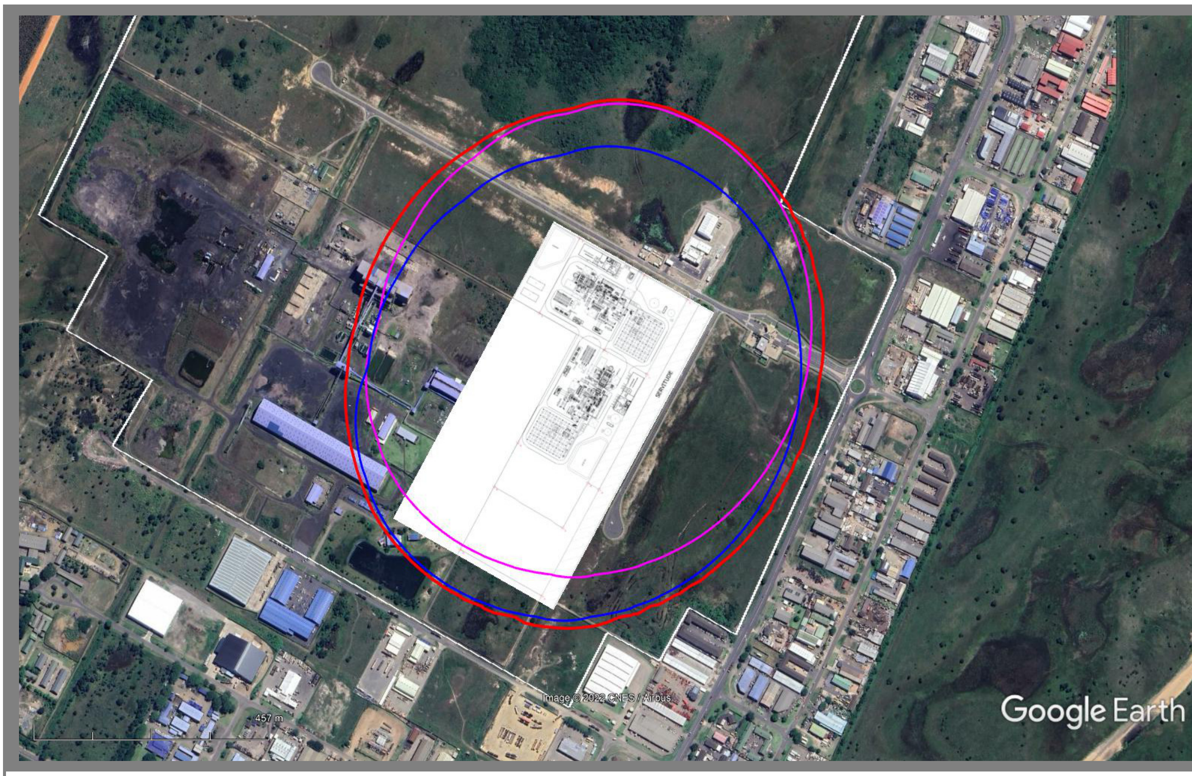
It should be noted that suggested mitigations are for consideration only. RISCOM does not imply that the suggested mitigation should be implemented or that any suggested mitigation is the only measure to reduce risks. Furthermore, implementation of some or all of the suggested mitigations would not guarantee full compliance with the Major Hazard Installation regulations.

Implementation of any mitigations should always be done in accordance with recognised engineering practices, using applicable codes and standards and be based on benefit versus cost principle.

6.1 Risk Ranking

This risk assessment considered numerous scenarios determining both consequences and a probability of release. Some scenarios have more serious consequences than others. However, the scenarios of particular interest are those with high-risk frequencies extending beyond the boundary of the site.

Figure 6-1 represents the $1x10^{-6}$ fatalities per person per year isopleth for the various site installations. The $1x10^{-6}$ fatalities per person per year isopleth is the lower limit for tolerable risks. The red curve represents the total site risk, while the other installations are shown in other colours. The major offsite incidents would be from the ammonia storage at the two gas turbines.



LEGEND	INSTALLATION
(red line)	Combined site
(magenta line)	Ammonia storage (Gas turbine - North)
(blue line)	LPG product pump (Gas turbine - South)

Figure 6-1: Comparison of the $1x10^{-6}$ fatalities per person per year isopleth for various site installations

6.2 Mitigation

As mentioned, the scenarios with the highest risk rankings are the ammonia operations. Suggested mitigation is listed in the following subsections.

6.2.1 Ammonia Storage

The major risk for the proposed PRBGP3 is the ammonia storage. This can be reduced in a number of ways including, but not limiting to reduction of the ammonia inventory on site or the substitution of ammonia. For example, ammonia hydroxide, due to the combination with water, will have a lower risk.

6.2.2 Process Hazard Analysis (PHA)

Hazardous areas should be reviewed using detailed Process Hazard Analysis (PHA)[1] such as a HAZOP study that should be completed to identify potential hazards, and suggest further mitigation for safer operations.

6.2.3 Ignition Sources

Ignition sources near the depot must be minimised as far as possible. This is particularly relevant with the natural gas usage.

A hazardous area classification as per SANS 10108 must be developed for all flammable materials. Only suitable instrumentation and electrical equipment should be installed in accordance with the requirement of the code.

6.2.4 Emergency Shut Down System (ESD)

The fast detection of a loss of containment with appropriate shut-down action to limit the amount of natural gas released, will assist in the reduction of the site risks.

1 A Process Hazard Analysis is not a regulated activity but mealy identifies potential hazards and recommends mitigation

7 IMPACT ASSESSMENT

As described in the terms of reference of the project, assessment of the Impacts of the loss of containment scenarios considered in this study, took cognisance of the following aspects as they related to local population:

- An assessment of the magnitude of the impacts (the consequences of the project on members of the surrounding public);
- An assessment of the significance of the impacts, taking into account the sensitivity of the receptors;
- Development of mitigation measures to avoid, reduce or manage the impacts; and,
- Assessment of the residual significant impacts after applying the mitigation measures.

The criteria that were used in impact assessment are summarised below (verbatim from the terms of reference document):

- The **nature**, which shall include a description of what causes the effect, what will be affected and how it will be affected.
- The **extent**, wherein it will be indicated whether the impact will be local (limited to the immediate area or site of development) or regional, and a value between 1 and 5 will be assigned as appropriate (with 1 being low and 5 being high).
- The **duration**, wherein it will be indicated whether:
  - the lifetime of the impact will be of a very short duration (0–1 years) – assigned a score of 1;
  - the lifetime of the impact will be of a short duration (2-5 years) - assigned a score of 2;
  - medium-term (5–15 years) – assigned a score of 3;
  - long term (> 15 years) - assigned a score of 4; or,
  - permanent - assigned a score of 5.
- The **magnitude**, quantified on a scale from 0-10, where a score is assigned:
  - 0 is small and will have no effect on the environment;
  - 2 is minor and will not result in an impact on processes;
  - 4 is low and will cause a slight impact on processes;
  - 6 is moderate and will result in processes continuing but in a modified way;
  - 8 is high (processes are altered to the extent that they temporarily cease);
  - 10 is very high and results in complete destruction of patterns and permanent cessation of processes.
- The **probability of occurrence**, which shall describe the likelihood of the impact actually occurring. Probability will be estimated on a scale of 1–5, where:
  - 1 is very improbable (probably will not happen);
  - 2 is improbable (some possibility, but low likelihood), 3 is probable (distinct possibility), 4 is highly probable (most likely); and,
  - 5 is definite (impact will occur regardless of any prevention measures).
- The **significance**, which shall be determined through a synthesis of the characteristics described above and can be assessed as low, medium or high; and,
- the **status**, which will be described as either positive, negative or neutral:
  - the degree to which the impact can be reversed;

- the degree to which the impact may cause irreplaceable loss of resources;
- the degree to which the impact can be mitigated.

The significance is calculated by combining the criteria in the following formula:

S = (E+D+M) P

S = Significance weighting
E = Extent
D = Duration
M =Magnitude
P = Probability

The significance weightings for each potential impact are as follows:

- < 30 points: Low (i.e., where this impact would not have a direct influence on the decision to develop in the area),
- 30-60 points: Medium (i.e., where the impact could influence the decision to develop in the area unless it is effectively mitigated),
- > 60 points: High (i.e., where the impact must have an influence on the decision process to develop in the area).

7.1 Methodology - Cumulative Impacts

"Cumulative Impact", in relation to an activity means the past, current and reasonably foreseeable future impact of an activity, considered together with the impact of activities associated with that activity, that in itself may not be significant, but may become significant when added to existing and reasonably foreseeable impacts eventuating from similar or diverse activities.

The role of the cumulative assessment is to test if such impacts are relevant to the proposed project in the proposed location (i.e., whether the addition of the proposed project in the area will increase the impact).

This section addresses whether the construction of the proposed development will result in:

- Unacceptable risk;
- Unacceptable loss;
- Complete or whole-scale changes to the environment or sense of place;
- Unacceptable increase in impact.

7.2 Impact Assessment of the proposed PRBGP3 Thermal Generation Facility at Richards Bay

7.2.1 Natural Gas Pipeline

The following is the impact assessment of the natural gas installations:

Table 7-1: Impact Assessment of natural gas pipeline

Nature:

Worst case loss of containment scenario – catastrophic rupture of natural gas pipeline leading to a fireball event, flammable vapour dispersion and ignition leading to flash fire thermal radiation effects and/or vapour cloud explosion overpressure effects.

	Without Mitigation	With Mitigation
Extent	Low (2)	Low (1)
Duration	Permanent (5)	Permanent (5)
Magnitude	High (8)	High (6)
Probability	Very improbable (1)	Very improbable (1)
Significance	Low (15)	Low (12)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible (worst case: death)	Irreversible (worst case: death)
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Mitigation:

Mitigation would include emergency response arrangements and systems, such as alarms and shutdown systems to allow for personnel to muster in case of emergency, as well as fire-fighting systems and cooperation with emergency responders. Preventive measures would include maintenance procedures to prevent the occurrence of a catastrophic loss of containment from corrosion, fire and gas detection and firewater systems to prevent escalation as well as strict control of ignition sources and other measures, which may be required according to standards such as those prescribed by the South African National Standards system.

Residual Risks:

Even with mitigation, there may be residual risk of occurrence due to failures in protection systems and break-down in procedures and documented systems.

7.2.2 Diesel Installation

The following is the impact assessment of the diesel installations:

Table 7-2: Impact Assessment of Diesel Installations

Nature:

Worst case loss of containment scenario – catastrophic rupture of diesel storage vessel leading to a pool fire with impacts not extending beyond the site boundary.

	Without Mitigation	**With Mitigation**
Extent	Low (2)	Low (1)
Duration	Very short (5)	Very short (5)
Magnitude	High (6)	High (6)
Probability	Very improbable (1)	Very improbable (1)
Significance	Low (13)	Low (20)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible (worst case: death)	Irreversible (worst case: death)
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Mitigation:

Mitigation would include emergency response arrangements and systems, such as alarms to allow for personnel to muster in case of emergency, as well as fire-fighting systems and cooperation with emergency responders. Preventive measures would include maintenance procedures to prevent the occurrence of a catastrophic loss of containment from corrosion, fire and gas detection and firewater systems to prevent escalation, as well as strict control of ignition sources and other measures, which may be required according to standards such as those prescribed by the South African National Standards system.

Residual Risks:

Even with mitigation, there may be residual risk of occurrence due to failures in protection systems and break-down in procedures and documented systems.

7.2.3 Hydrogen Installation

The following is the impact assessment of the hydrogen storage installations:

Table 7-3: Impact Assessment of Diesel Installations

Nature:

Worst case loss of containment scenario – catastrophic rupture of hydrogen storage vessel leading to leading to a fireball event, flammable vapour dispersion and ignition leading to flash fire thermal radiation effects and/or vapour cloud explosion overpressure effects.

	Without Mitigation	With Mitigation
Extent	Low (2)	Low (1)
Duration	Very short (5)	Very short (5)
Magnitude	High (6)	High (6)
Probability	Very improbable (1)	Very improbable (1)
Significance	Low (13)	Low (20)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible (worst case: death)	Irreversible (worst case: death)
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Mitigation:

Mitigation would include emergency response arrangements and systems, such as alarms to allow for personnel to muster in case of emergency, as well as fire-fighting systems and cooperation with emergency responders. Preventive measures would include maintenance procedures to prevent the occurrence of a catastrophic loss of containment from corrosion, fire and gas detection and firewater systems to prevent escalation, as well as strict control of ignition sources and other measures, which may be required according to standards such as those prescribed by the South African National Standards system.

Residual Risks:

Even with mitigation, there may be residual risk of occurrence due to failures in protection systems and break-down in procedures and documented systems.

7.2.4 Ammonia Storage

The following is the impact assessment of the Ammonia installations:

Table 7-4: Impact Assessment of ammonia storage

Nature:

Worst case loss of containment of ammonia scenario – leading to a release of toxic airborne plumes.

	Without Mitigation	**With Mitigation**
Extent	Low (2)	Low (1)
Duration	Very short (5)	Very short (5)
Magnitude	High (8)	High (6)
Probability	Very improbable (1)	Very improbable (1)
Significance	Low (15)	Low (12)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible (worst case: death)	Irreversible (worst case: death)
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Mitigation:

Mitigation would include reduction of ammonia or substitution for a less toxic component emergency response arrangements and systems, such as alarms to allow for personnel to muster in case of emergency, and cooperation with emergency responders. Preventive measures would include design, installation according to the vendor requirements. Furthermore, the layout separation distances between battery storage units and other units to prevent knock-on effects.

Residual Risks:

Even with mitigation, there may be residual risk of occurrence due to failures in protection systems and break-down in procedures and documented systems.

7.2.5 Cumulative Impact Assessment

This section considers all impacts in the preceding Section 7.2 and the cumulative impact of all installations.

The risks of the site are dominated by the ammonia storage, and thus the cumulative impact will be identical to the ammonia storage.

Table 7-5: Cumulative impact of project as a whole

Nature:

Worst case loss of containment of ammonia scenario – leading to a release of toxic airborne plumes.

	Without Mitigation	With Mitigation
Extent	Low (2)	Low (1)
Duration	Very short (5)	Very short (5)
Magnitude	High (8)	High (6)
Probability	Very improbable (1)	Very improbable (1)
Significance	Low (15)	Low (12)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible (worst case: death)	Irreversible (worst case: death)
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Mitigation:

Mitigation would include reduction of ammonia or substitution for a less toxic component emergency response arrangements and systems, such as alarms to allow for personnel to muster in case of emergency, and cooperation with emergency responders. Preventive measures would include design, installation according to the vendor requirements. Furthermore, the layout separation distances between battery storage units and other units to prevent knock-on effects.

Residual Risks:

Even with mitigation, there may be residual risk of occurrence due to failures in protection systems and break-down in procedures and documented systems.

Information relating to the nearby installations of the Gas to Power facility, namely the chlor-alkali facility and the Tata Alloys are both unknown, and thus not included in the cumulative area analysis.

8 CONCLUSIONS

Risk calculations are not precise. Accuracy of predictions is determined by the quality of base data and expert judgements.

This risk assessment included the consequences of fires and explosions at the proposed PRBGP3 facility in Richards Bay. A number of well-known sources of incident data were consulted and applied to determine the likelihood of an incident to occur.

This risk assessment was performed with the assumption that the site would be maintained to an acceptable level and that all statutory regulations would be applied. It was also assumed that the detailed engineering designs would be done by competent people, and would be correctly specified for the intended duty. For example, it was assumed that tank wall thicknesses have been correctly calculated, that vents have been sized for emergency conditions, that instrumentation and electrical components comply with the specified electrical area classification, that material of construction is compatible with the products, etc.

It is the responsibility of the owners and their contractors to ensure that all engineering designs would have been completed by competent persons, and that all pieces of equipment would have been installed correctly. All designs should be in full compliance with (but not limited to) the Occupational Health and Safety Act 85 of 1993 and its regulations, the National Buildings Regulations and the Buildings Standards Act 107 of 1977 as well as local bylaws.

A number of incident scenarios were simulated, taking into account the prevailing meteorological conditions, and described in the report.

8.1 Notifiable Substances

The General Machinery Regulation 8 and its Schedule A on notifiable substances, requires any employer who has a substance equal to or exceeding the quantity listed in the regulation to notify the divisional director. A site is classified as a Major Hazard Installation if it contains one or more notifiable substances, or if the off-site risk is sufficiently high. The latter can only be determined from a quantitative risk assessment.

The notifiable threshold for ammonia is listed 20 t in a single vessel. As the proposed installation exceeds the threshold limit, ammonia will be classified as a notifiable substance, which would automatically **classify the facility a Major Hazard Installation**.

8.2 Power Plant and Associated Equipment

Hazardous substances associated with this facility would include; ammonia; hydrogen, diesel and natural gas. Of the listed substances, only ammonia could result in offsite fatalities.

The risk of 1×10^{-6} fatalities per person per year isopleth found to extend beyond the site boundary, and **that alone qualifies the site as a Major Hazard Installation**. The risk of 1×10^{-4} fatalities per person per year, representing intolerable to the general public, was found to remain within the site boundary. Reducing the risks, particularly relating to ammonia, could not only reduce the risks of the facility, but could alter the MHI classification of the proposed PRBGP3 facility in Richards Bay.

8.3 Impacts onto Neighbouring Properties, Residential Areas and Major Hazard Installations

A large release of ammonia could extend a considerable downward distance impacting the commercial and residential areas of Richards Bay. However, fatalities will be limited to the Alton industrial area and will not impact residential areas.

No residential area or vulnerable institutions would be seriously impacted with the construction and operation of the proposed PRBGP3.

8.4 Major Hazard Installation

This investigation concluded that under the current design conditions, the proposed PRBGP3 facility in Richards Bay **would be considered as a Major Hazard Installation** and would require notification in accordance with the MHI regulations.

Kindly note that this study is not intended to replace the Major Hazard Installation risk assessment, which should be completed prior to construction of the terminal once final designs are available.

8.5 Land Planning Restrictions

The risks generated from this study concluded that the risk isopleths generated from the proposed project could have risks within the ALARP range, resulting in land planning restrictions. As the designs have not been finalised, the full land planning restrictions must be taken from the Major Hazard Installation risk assessment report.

9 RECOMMENDATIONS

As a result of the risk assessment study conducted for the proposed PRBGP3 facility in Richards Bay, a number of events were found to have risks beyond the site boundary. These risks could be mitigated to acceptable levels, as shown in the report.

RISCOM did not find any fatal flaws that would prevent the project proceeding to the detailed engineering phase of the project, and would support the project under the following conditions most of which will be detailed in the MHI study:

- Compliance with all statutory requirements, i.e., pressure vessel designs;
- Compliance with applicable SANS codes, i.e., SANS 10087, SANS 10089, SANS 10108, etc. ;
- Incorporation of applicable guidelines or equivalent international recognised codes of good design and practice into the designs;
- Completion of a recognised process hazard analysis (such as a HAZOP study, FMEA, etc.) on the proposed facility prior to construction to ensure design and operational hazards have been identified and adequate mitigation put in place;
- Full compliance with IEC 61508 and IEC 61511 (Safety Instrument Systems) standards or equivalent to ensure that adequate protective instrumentation is included in the design and would remain valid for the full life cycle of the tank farm:
    - Including demonstration from the designer that sufficient and reliable instrumentation would be specified and installed at the facility;
- Preparation and issue of a safety document detailing safety and design features reducing the impacts from fires, explosions and flammable atmospheres to the MHI assessment body at the time of the MHI assessment:
    - Including compliance to statutory laws, applicable codes and standards and world's best practice;
    - Including the listing of statutory and non-statutory inspections, giving frequency of inspections;
    - Including the auditing of the built facility against the safety document;
    - Noting that codes such as IEC 61511 can be used to achieve these requirements;
- Demonstration by the PRBGP3 owner or their contractor that the final designs would reduce the risks posed by the installation to the South African requirements as prescribed in SANS 1461 (2018);
- Signature of all terminal designs by a professional engineer registered in South Africa in accordance with the Professional Engineers Act, who takes responsibility for suitable designs;
- Completion of an emergency preparedness and response document for on-site and off-site scenarios prior to initiating the MHI risk assessment (with input from local authorities);
- Any increases to the product list or product inventories must be with the approval of the authorities under NEMA;
- Final acceptance of the facility risks with an MHI risk assessment that must be completed in accordance with the MHI regulations;
    - Basing such a risk assessment on the final design and including engineering mitigation.

10 REFERENCES

CPR 12E (2005). *Methods for Determining and Processing Probabilities ("Red Book")*. Fourth Edition. Apeldoorn: TNO.

CPR 14E (1997). *Methods for the Calculation of Physical Effects ("Yellow Book")*. Third Edition. Apeldoorn: TNO.

CPR 18E (1999). *Guidelines for Quantitative Risk Assessment ("Purple Book")*. First Edition, Apeldoorn: TNO.

DOL (2001). *Occupation Health and Safety Act, 1993: Major Hazard Installation Regulations (No. R692)*. Regulation Gazette. No. 7122, Pretoria, Republic of South Africa: Government Gazette.

HSE (2011). *PADHI: HSE's Land Use Planning Methodology*. Available at: Health and Safety Executive Website. http://www.hse.gov.uk/landuseplanning/ methodology.htm

IGEM/TD/2 (2012) *Assessing the risks from high pressure natural gas pipelines*. Kegworth Institution. of Gas Engineers and Managers

RIVM (2009). *Reference Manual BEVI Risk Assessments*. Edition 3.2. Bilthoven, the Netherlands: National Institute of Public Health and the Environment (RIVM).

SANS 1461 (2018). *Major hazard Installation- Risk Assessment*. Edition 1, Pretoria, South African Bureau of Standards (SABS)

STEPHENS, M. (1970). *Minimizing Damage to Refineries*. US Dept. of the Interior, Offices of Oil and Gas.

https://spectrum.ieee.org/energywise/energy/batteries-storage/dispute-erupts-over-what-sparked-an-explosive-liion-energy-storage-accident

11 ABBREVIATIONS AND ACRONYMS

AIA	See **Approved Inspection Authority**
ALARP	The UK Health and Safety Executive (HSE) developed the risk **ALARP** triangle, in an attempt to account for risks in a manner similar to those used in everyday life. This involved deciding: • Whether a risk is so high that something must be done about it; • Whether the risk is or has been made so small that no further precautions are necessary; • Whether a risk falls between these two states and has been reduced to levels '**as low as reasonably practicable'** (ALARP). Reasonable practicability involves weighing a risk against the trouble, time and money needed to control it.
API	The **American Petroleum Institute** is the largest U.S. trade association for the oil and natural gas industry. It claims to represent nearly 600 corporations involved in production, refinement, distribution, and many other aspects of the petroleum industry.
Approved Inspection Authority	An **approved inspection authority** (AIA) is defined in the Major Hazard Installation regulations (July 2001)
Asphyxiant	An **asphyxiant** is a gas that is nontoxic but may be fatal if it accumulates in a confined space and is breathed at high concentrations since it replaces oxygen containing air.
Blast Overpressure	**Blast overpressure** is a measure used in the multi-energy method to indicate the strength of the blast, indicated by a number ranging from 1 (for very low strengths) up to 10 (for detonative strength).
BLEVE	**Boiling liquid expanding vapour explosions** result from the sudden failure of a vessel containing liquid at a temperature above its boiling point. A **BLEVE** of flammables results in a large fireball.
CCGT	A **closed-cycle gas turbine** is a turbine that uses a gas (e.g., air, nitrogen, helium, argon, etc.) for the working fluid as part of a closed thermodynamic system. Heat is supplied from an external source. Such recirculating turbines follow the Brayton cycle.
Detonation	**Detonation** is a release of energy caused by extremely rapid chemical reaction of a substance, in which the reaction front of a substance is determined by compression beyond the auto-ignition temperature.
EIA	**Environmental assessment** is the assessment of the environmental consequences of a plan, policy, program, or actual projects prior to the decision to move forward with the proposed action.
Emergency Plan	An **emergency plan** is a plan in writing that describes how potential incidents identified at the installation together with their consequences should be dealt with, both on site and off site.
ERPG	**Emergency response planning guidelines** were developed by the American Industrial Hygiene Association. **ERPG-1** is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing anything other than mild transient adverse health effects or perceiving a clearly defined objectionable odour. **ERPG-2** is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without

	experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. **ERPG-3** is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
ESD	**Emergency Shutdown System (ESD)** is designed to minimize the consequences of **emergency** situations, related to typically uncontrolled flooding, escape of hydrocarbons, or outbreak of fire in hydrocarbon carrying areas or areas which may otherwise be hazardous.
Explosion	An **explosion** is a release of energy that causes a pressure discontinuity or blast wave.
Flammable Limits	**Flammable limits** are a range of gas or vapour concentrations in the air that will burn or explode if a flame or other ignition source is present. The lower point of the range is called the lower flammable limit (LFL). Likewise, the upper point of the range is called the upper flammable limit (UFL).
Flammable Liquid	The Occupational Health and Safety Act 85 of 1993 defines a **flammable liquid** as any liquid which produces a vapour that forms an explosive mixture with air and includes any liquid with a closed cup flashpoint of less than 55°C. Flammable products have been classified according to their flashpoints and boiling points, which ultimately determine the propensity to ignite. Separation distances described in the various codes are dependent on the flammability classification. **Class Description** 0 Liquefied petroleum gas (LPG) IA Liquids that have a closed cup flashpoint of below 23°C and a boiling point below 35°C IB Liquids that have a closed cup flashpoint of below 23°C and a boiling point of 35°C or above IC Liquids that have a closed cup flashpoint of 23°C and above but below 38°C II Liquids that have a closed cup flashpoint of 38°C and above but below 60.5°C IIA Liquids that have a closed cup flashpoint of 60.5°C and above but below 93°C
Flash Fire	A **flash fire** is defined as combustion of a flammable vapour and air mixture in which the flame passes through the mixture at a rate less than sonic velocity so that negligible damaging overpressure is generated.
FMEA	**Failure mode and effects analysis** is the process of reviewing as many components, assemblies, and subsystems as possible to identify potential failure modes in a system and their causes and effects
Frequency	**Frequency** is the number of times an outcome is expected to occur in a given period of time.
FW	**Fire Water**
GCB	**Gas Circuit Breakers** are vital equipment for protecting transmission systems. They cut off current instantly in the event of a system failure due to lightning or other issues.
GIS	**Gas Insulated Switchgear (GIS)** is the name for a unit that houses these components and circuits in a single gas tank with a compact footprint. Grounding devices that prevent electrical shock and lightning

	arresters that prevent dielectric breakdowns from lightning strikes are also included to enhance safety.
GSU	**Generator step-up transformers (GSU)** are the critical link between the power station and the transmission network, often operated day and night at full load. They must be built to withstand extreme thermal loading without ageing prematurely.
HAZOP	A **hazard and operability study (HAZOP**) are a structured and systematic examination of a complex planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment.
HEL	The maximum concentration of a gas or vapor that will burn in air is defined as the **Upper Explosive Limit (UEL)**. Above this level, the mixture is too “rich” to burn. The range between the LEL and UEL is known as the flammable **range** for that gas or vapor.
HRSG	A **heat recovery steam generator** is a kind of heat exchanger that recovers heat from the exhaust gases of a gas turbine to an extreme degree. The heat is recovered in the form of steam which is served as the power source of a power-generating steam turbine.
HV	**High voltage** electricity refers to electrical potential large enough to cause injury or damage. In certain industries, high voltage refers to voltage above a certain threshold. Equipment and conductors that carry high voltage warrant special safety requirements and procedures.
IDZ	**Industrial development zones (IDZs)** or special economic zones (SEZs) are specific geographical areas in a country where certain economic activities are promoted through a set of policy measures not generally applicable to the rest of the country.
Ignition Source	An **ignition source** is a source of temperature and energy sufficient to initiate combustion.
Individual Risk	**Individual risk** is the probability that in one year a person will become a victim of an accident if the person remains permanently and unprotected in a certain location. Often the probability of occurrence in one year is replaced by the frequency of occurrence per year.
Isopleth	See **Risk Isopleth**
Jet	A **jet** is the outflow of material emerging from an orifice with significant momentum.
Jet Fire or Flame	A **jet fire or flame** is combusting material emerging from an orifice with a significant momentum.
LEL	**Lower Explosive Limit** is defined as the lowest concentration (by percentage) of a gas or vapor in air that is capable of producing a flash of fire in presence of an ignition source (arc, flame, heat). ... In concentrations of 0-5% Methane in air, the mixture is too lean to ignite or burn.
LFL	**Lower Flammable Limit** see Flammable Limits
LPG	**Liquefied natural gas** (**LPG**) is natural gas (predominantly methane, CH_4, with some mixture of ethane, C_2H_6) that has been cooled down to liquid form for ease and safety of non-pressurized storage or transport.
LOC	See **Loss of Containment**
Local Government	**Local government** is defined in Section 1 of the Local Government Transition Act, 1993 (Act No. 209 of 1993).
Loss of Containment	**Loss of containment** (LOC) is the event resulting in a release of material into the atmosphere.

Major Hazard Installation	**Major Hazard Installation** (MHI) means an installation: • Where more than the prescribed quantity of any substance is or may be kept, whether permanently or temporarily; • Where any substance is produced, used, handled or stored in such a form and quantity that it has the potential to cause a major incident (the potential of which will be determined by the risk assessment).
Major Incident	A **major incident** is an occurrence of catastrophic proportions, resulting from the use of plant or machinery or from activities at a workplace. When the outcome of a risk assessment indicates that there is a possibility that the public will be involved in an incident, then the incident is catastrophic.
Material Safety Data Sheet	According to ISO-11014, a **material safety data sheet (MSDS)** is a document that contains information on the potential health effects of exposure to chemicals or other potentially dangerous substances and on safe working procedures when handling chemical products. It is an essential starting point for the development of a complete health and safety program. It contains hazard evaluations on the use, storage, handling and emergency procedures related to that material. An MSDS contains much more information about the material than the label and it is prepared by the supplier. It is intended to tell what the hazards of the product are, how to use the product safely, what to expect if the recommendations are not followed, what to do if accidents occur, how to recognize symptoms of overexposure and what to do if such incidents occur.
MHI	See **Major Hazard Installation**
MIR	**Maximum Individual Risk** (see Individual Risk)
MSDS	See **Material Safety Data Sheet**
MV	**Medium Voltage** Busbar consists of Copper and Aluminium conductors embedded within a homogeneous insulation alloy of pure silicon minerals and epoxy resin, thereby ensuring high mechanical strength and chemical resistance.
NEMA	**National Environmental Management Act 107 of 1998, abbreviated (NEMA)** is the statutory framework to enforce Section 24 of the Constitution of the Republic of South Africa. The **NEMA** is intended to promote co-operative governance and ensure that the rights of people are upheld, but also recognising the necessity of economic development.
OHS Act	**Occupational Health and Safety Act**, 1993 (Act No. 85 of 1993)
PAC	See **Protective Action Criteria**
PADHI	**PADHI** (**planning advice for developments near hazardous installations**) is the name given to a methodology and software decision support tool developed and used in the HSE. It is used to give land-use planning (LUP) advice on proposed developments near hazardous installations. PADHI uses two inputs into a decision matrix to generate either an ‘advise against’ or ‘don’t advise against’ response: • The zone in which the development is located of the three zones that HSE sets around the major hazard: o The inner zone (> $1x10^{-5}$ fatalities per person per year); o The middle zone ($1x10^{-5}$ fatalities per person per year to $1x10^{-6}$ fatalities per person per year);

	o The outer zone ($1x10^{-6}$ fatalities per person per year to $3x10^{-7}$ fatalities per person per year); • The 'sensitivity level' of the proposed development which is derived from an HSE categorisation system of 'development types' (see the 'development type tables' in Appendix B).
PHA	A **process hazard analysis** is a set of organized and systematic assessments of the potential hazards associated with an industrial process.
POST	**The Parliamentary Office of Science and Technology** is the Parliament of the United Kingdom's in-house source of independent, balanced and accessible analysis of public policy issues related to science and technology.
PPM	This is an abbreviation for **"parts per million"** and it also can be expressed as milligrams per liter (mg/L). This measurement is the mass of a chemical or contaminate per unit volume of water.
QRA	See **Quantitative Risk Assessment**
Quantitative Risk Assessment	A **quantitative risk assessment** is the process of hazard identification, followed by a numerical evaluation of effects of incidents, both consequences and probabilities and their combination into the overall measure of risk.
RBIDZ	**Richards Bay Industrial Development Zone**
Risk	**Risk** is the measure of the consequence of a hazard and the frequency at which it is likely to occur. Risk is expressed mathematically as: **Risk = Consequence x Frequency of Occurrence**
Risk Assessment	**Risk assessment** is the 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 required to remove, reduce or control potential causes of such an incident.
Risk Contour	See **Risk Isopleth**
SANAS	The **South African National Accreditation System (SANAS)** is the only national body responsible for carrying out accreditations in respect of conformity assessment, as mandated through the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act (Act 19 of 2006).
Societal Risk	**Societal risk** is risk posed on a societal group who are exposed to a hazardous activity.
UFL	**Upper Flammable Limit** (see Flammable Limits)
Vapour Cloud Explosion	A **vapour cloud explosion (VCE)** results from ignition of a premixed cloud of a flammable vapour, gas or spray with air, in which flames accelerate to sufficiently high velocities to produce significant overpressure.
VCE	See **Vapour Cloud Explosion**

12 APPENDIX A: NOTIFICATION OF MAJOR HAZARD INSTALLATION

Prior to assessment of potential impacts of various accidental spills, reference needs to be made to the legislation, regulations and guidelines governing the operation of the development.

Section 1 of the Occupational Health and Safety Act (OHS Act; Act No. 85 of 1993) defines a "major hazard installation" to mean an installation:

" (a) *Where more than the prescribed quantity of any substance is or may be kept, whether permanently or temporarily;*

(b) *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 (our emphasis).* "

It should be noted that if either (a) or (b) is satisfied, the Major Hazard Installation (MHI) regulations will apply. The prescribed quantity of a chemical can be found in Section 8 (1) of the General Machinery Regulation 8 (our emphasis).

A major incident is defined as: "an occurrence of catastrophic proportions, resulting from the use of plant and machinery or from activities at a workplace". Catastrophic in this context means loss of life and limbs or severe injury to employees or members of the public, particularly those who are in the immediate vicinity (our emphasis).

It is important to note that the definition refers to an occurrence, whereas Section 1b) refers to potential to cause a major incident. If potential to cause a major incident exists, then the OHS Act and the Major Hazard Installation regulations will apply (our emphasis).

On the 16th of January 1998, the MHI regulations were promulgated under the OHS Act (Act No. 85 of 1993), with a further amendment on the 30th of July 2001. The provisions of the regulations apply to installations that have on their premises a certain quantity of a substance that can pose a significant risk to the health and safety of employees and the public.

The scope of application given in Section 2 of the MHI regulations is as follows:

" (1) *Subject to the provisions of Sub regulation (3) these regulations shall apply to employers, self-employed persons and users, who have on their premises, either permanently or temporarily, a major hazard installation or a quantity of a substance which may pose a risk that could affect the health and safety of employees and the public (our emphasis);*

(2) *These regulations shall apply to local governments, with specific reference to Regulation 9.* "

It is important to note that the regulations refer to a substance, and furthermore the regulations are applicable to risks posed by the substance and **NOT** merely the potential consequences (our emphasis).

The regulations essentially consist of six parts, namely:

1. Duties for notification of a Major Hazard Installation (existing or proposed), including:
   a. Fixed (see List 1);
   b. Temporary installations;
2. Minimum requirements for a quantitative risk assessment (see List 2);
3. Requirements of an on-site emergency plan (see List 3);
4. Reporting steps of risk and emergency occurrences (see List 4);
5. General duties required of suppliers;
6. General duties required of local government.

Notification of installation (List 1) indicates that:

- Applications need to be made in writing to the relevant local authority and the provincial director for permission:
  - To erect any Major Hazard Installation;
  - Prior to the modification of any existing installation that may significantly increase risk related to it (e.g., an increase in storage or production capacity or alteration of a process);
- Applications need to include the following information:
  - The physical address of installation;
  - Complete material safety data sheets of all hazardous substances;
  - The maximum quantity of each substance envisaged to be on premises at any one time;
  - The risk assessment of the installation (see List 2);
  - Any further information that may be deemed necessary by an inspector in interests of health and safety to the public;
- Applications need to be advertised in at least one newspaper serving the surrounding communities and by way of notices posted within these communities.

The risk assessment (List 2):

- Is the 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 measures required to remove, reduce or control the potential causes of such an incident;
- Needs to be undertaken at intervals not exceeding 5 years and needs to be submitted to the relevant local emergency services;
- Must be made available in copies to the relevant health and safety committee, with 60 days given to comment thereon and the results of the assessment made available to any relevant representative or committee to comment thereon;
- Should be undertaken by competent person(s) and include the following:
    - A general process description;
    - A description of major incidents associated with this type of installation and consequences of such incidents (including potential incidents);
    - An estimation of the probability of a major incident;
    - The on-site emergency plan;
    - An estimation of the total result in the case of an explosion;
    - An estimation of the effects of thermal radiation in the case of fire;
    - An estimation of concentration effects in the case of a toxic release;
    - Potential effects of a major incident on an adjacent major hazard installation or part thereof;
    - Potential effects of a major incident on any other installation, members of the public (including all persons outside the premises) and on residential areas;
    - Meteorological tendencies;
    - Suitability of existing emergency procedures for risks identified;
    - Any requirements laid down in terms of the Environmental Conservation Act of 1989 (Act No. 73 of 1989);
    - Any organisational measures that may be required;
- The employer shall ensure that the risk assessment is of an acceptable standard and shall be reviewed should:
    - It be suspected that the preceding assessment is no longer valid;
    - Changes in the process that affect hazardous substances;
    - Changes in the process that involve a substance that resulted in the installation being classified a Major Hazard Installation or in the methods, equipment or procedures for the use, handling or processing of that substance;
    - Incidents that have brought the emergency plan into operation and may affect the existing risk assessment;
- Must be made available at a time and place and in a manner agreed upon between parties for scrutiny by any interested person that may be affected by the activities.

Requirements related to the on-site emergency plan (List 3) are:

- After submission of the notification, the following shall be established:
  - An on-site emergency plan must be made available and must be followed inside the premises of the installation or the part of the installation classified as a Major Hazard Installation, in consultation with the relevant health and safety representative or committee;
  - The on-site emergency plan must be discussed with the relevant local government, taking into consideration any comment on the risk related to the health and safety of the public;
  - The on-site emergency plan must be reviewed and where necessary updated, in consultation with the relevant local government, at least once every three years;
  - A copy of the on-site emergency plan must be signed in the presence of two witnesses, who shall attest the signature;
  - The on-site emergency plan must be readily available at all times for implementation and use;
  - All employees must be conversant with the on-site emergency plan;
  - The on-site emergency plan must be tested in practice at least once a year, and a record must be kept of such testing;
- Any employer, self-employed person and user owning or in control of a pipeline that could pose a threat to the general public shall inform the relevant local government and shall be jointly responsible with the relevant local government for establishment and implementation of an on-site emergency plan.

In reporting of risk and emergency occurrences (List 4):

- Following an emergency occurrence, the user of the installation shall:
  - Subject to the provisions of Regulation 6 of the General Administrative Regulations, within 48 hours by means of telephone, facsimile or similar means of communication, inform the chief inspector, the provincial director and relevant local government of the occurrence of a major incident or an incident that brought the emergency plan into operation or any near miss;
  - Submit a report in writing to the chief inspector, provincial director and local government within seven days;
  - Investigate and record all near misses in a register kept on the premises, which shall at all times be available for inspection by an inspector and local government representatives.

The duties of the supplier refer specifically to:

- Supplying of material safety data sheets for hazardous substances employed or contemplated at the installation;
- Assessment of the circumstances and substance involved in an incident or potential incident and the informing all persons being supplied with that substance of the potential dangers surrounding it;
- Provision of a service that shall be readily available on a 24-hour basis to all employers, self-employed persons, users, relevant local government and any other body concerned to provide information and advice in the case of a major incident with regard to the substance supplied.

The duties of local government are summarised as follows:

" 9. (1) *Without derogating from the provisions of the National Building Regulations and Building Standards Act of 1977 (Act No. 103 of 1977), no local government shall permit the erection of a new major hazard installation at a separation distance less than that which poses a risk to:*

(a) Airports;

(b) Neighbouring independent major hazard installations;

(c) Housing and other centres of population; or,

(d) Any other similar facility…

Provided that the local government shall permit new property development only where there is a separation distance which will not pose a risk (our emphasis) in terms of the risk assessment: Provided further that the local government shall prevent any development adjacent to an installation that will result in that installation being declared a major hazard installation.

(2) Where a local government does not have facilities available to control a major incident or to comply with the requirements of this regulation that local government shall make prior arrangements with a neighbouring local government, relevant provincial government or the employer, self-employed person and user for assistance…

(3) All off-site emergency plans to be followed outside the premises of the installation or part of the installation classified as a major hazard installation shall be the responsibility of the local government… "

13 APPENDIX B: PADHI LAND-PLANNING TABLES

13.1 Development Type Table 1: People at Work, Parking

Development Type	Examples	Development Detail and Size	Justification
DT1.1 Workplaces	Offices, factories, warehouses, haulage depots, farm buildings, nonretail markets, builder's yards	Workplaces (predominantly nonretail), providing for less than 100 occupants in each building and less than 3 occupied storeys (Level 1)	Places where the occupants will be fit and healthy and could be organised easily for emergency action Members of the public will not be present or will be present in very small numbers and for a short time
	Exclusions		
		DT1.1 x1 Workplaces (predominantly nonretail) providing for 100 or more occupants in any building or 3 or more occupied storeys in height (Level 2 except where the development is at the major hazard site itself, where it remains Level 1)	Substantial increase in numbers at risk with no direct benefit from exposure to the risk
	Sheltered workshops, Remploy	DT1.1 x2 Workplaces (predominantly nonretail) specifically for people with disabilities (Level 3)	Those at risk may be especially vulnerable to injury from hazardous events or they may not be able to be organised easily for emergency action
DT1.2 Parking Areas	Car parks, truck parks, lockup garages	Parking areas with no other associated facilities (other than toilets; Level 1)	
	Exclusions		
	Car parks with picnic areas or at a retail or leisure development or serving a park and ride interchange	DT1.2 x1 Where parking areas are associated with other facilities and developments the sensitivity level and the decision will be based on the facility or development	

13.2 Development Type Table 2: Developments for Use by the General Public

Development Type	Examples	Development Detail and Size	Justification
DT2.1 Housing	Houses, flats, retirement flats or bungalows, residential caravans, mobile homes	Developments up to and including 30 dwelling units and at a density of no more than 40 per hectare (Level 2)	Development where people live or are temporarily resident It may be difficult to organise people in the event of an emergency
	Exclusions		
	Infill, back-land development	DT2.1 x1 Developments of 1 or 2 dwelling units (Level 1)	Minimal increase in numbers at risk
	Larger housing developments	DT2.1 x2 Larger developments for more than 30 dwelling units (Level 3)	Substantial increase in numbers at risk
		DT2.1 x3 Any developments (for more than 2 dwelling units) at a density of more than 40 dwelling units per hectare (Level 3)	High-density developments
DT2.2 Hotel or Hostel or Holiday Accommodation	Hotels, motels, guest houses, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, accommodation centres, holiday caravan sites, camping sites	Accommodation up to 100 beds or 33 caravan or tent pitches (Level 2)	Development where people are temporarily resident It may be difficult to organise people in the event of an emergency
	Exclusions		
	Smaller: guest houses, hostels, youth hostels, holiday homes, halls of residence, dormitories, holiday caravan sites, camping sites	DT2.2 x1 Accommodation of less than 10 beds or 3 caravan or tent pitches (Level 1)	Minimal increase in numbers at risk
	Larger: hotels, motels, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, holiday caravan sites, camping sites	DT2.2 x2 Accommodation of more than 100 beds or 33 caravan or tent pitches (Level 3)	Substantial increase in numbers at risk

Development Type	Examples	Development Detail and Size	Justification
DT2.3 Transport Links	Motorway, dual carriageway	Major transport links in their own right i.e., not as an integral part of other developments (Level 2)	Prime purpose is as a transport link Potentially large numbers exposed to risk but exposure of an individual is only for a short period
	Exclusions		
	Estate roads, access roads	DT2.3 x1 Single carriageway roads (Level 1)	Minimal numbers present and mostly a small period of time exposed to risk Associated with other development
	Any railway or tram track	DT2.3 x2 Railways (Level 1)	Transient population, small period of time exposed to risk Periods of time with no population present

Development Type	Examples	Development Detail and Size	Justification
DT2.4 Indoor Use by Public	Food and drink: restaurants, cafes, drive-through fast food, pubs Retail: shops, petrol filling station (total floor space based on shop area not forecourt), vehicle dealers (total floor space based on showroom or sales building not outside display areas), retail warehouses, super-stores, small shopping centres, markets, financial and professional services to the public Community and adult education: libraries, art galleries, museums, exhibition halls, day surgeries, health centres, religious buildings, community centres. adult education, 6th form college, college of FE Assembly and leisure: Coach or bus or railway stations, ferry terminals, airports, cinemas, concert or bingo or dance halls, conference centres, sports or leisure centres, sports halls, facilities associated with golf courses, flying clubs (e.g., changing rooms, club house), indoor go kart tracks	Developments for use by the general public where total floor space is from 250 m^2 up to 5000 m^2 (Level 2)	Developments where members of the public will be present (but not resident) Emergency action may be difficult to coordinate
	Exclusions		
		DT2.4 x1 Development with less than 250 m^2 total floor space (Level 1)	Minimal increase in numbers at risk
		DT2.4 x2 Development with more than 5000 m^2 total floor space (Level 3)	Substantial increase in numbers at risk
DT2.5 Outdoor Use by Public	Food and drink: food festivals, picnic areas Retail: outdoor markets, car boot sales, funfairs	Principally an outdoor development for use by the general public i.e., developments	Developments where members of the public will be present (but

Development Type	Examples	Development Detail and Size	Justification
	Community and adult education: open-air theatres and exhibitions Assembly and leisure: coach or bus or railway stations, park and ride interchange, ferry terminals, sports stadia, sports fields or pitches, funfairs, theme parks, viewing stands, marinas, playing fields, children's play areas, BMX or go kart tracks, country parks, nature reserves, picnic sites, marquees	where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time (Level 2)	not resident) either indoors or outdoors Emergency action may be difficult to coordinate
	Exclusions		
	Outdoor markets, car boot sales, funfairs picnic area, park and ride interchange, viewing stands, marquees	DT2.5 x1 Predominantly open-air developments likely to attract the general public in numbers greater than 100 people but up to 1000 at any one time (Level 3)	Substantial increase in numbers at risk and more vulnerable due to being outside
	Theme parks, funfairs, large sports stadia and events, open air markets, outdoor concerts, pop festivals	DT2.5 x2 Predominantly open-air developments likely to attract the general public in numbers greater than 1000 people at any one time (Level 4)	Very substantial increase in numbers at risk, more vulnerable due to being outside Emergency action may be difficult to coordinate

13.3 Development Type Table 3: Developments for Use by Vulnerable People

Development Type	Examples	Development Detail and Size	Justification
DT3.1 Institutional Accommodation and Education	Hospitals, convalescent homes, nursing homes, old people's homes with warden on site or 'on call', sheltered housing, nurseries, crèches, schools and academies for children up to school leaving age	Institutional, educational and special accommodation for vulnerable people or that provides a protective environment (Level 3)	Places providing an element of care or protection Because of age, infirmity or state of health the occupants may be especially vulnerable to injury from hazardous events Emergency action and evacuation may be very difficult
	Exclusions		
	Hospitals, convalescent homes, nursing homes, old people's homes, sheltered housing	DT3.1 x1 24-hour care where the site on the planning application being developed is larger than 0.25 hectare (Level 4)	Substantial increase in numbers of vulnerable people at risk
	Schools, nurseries, crèches	DT3.1 x2 Day care where the site on the planning application being developed is larger than 1.4 hectare (Level 4)	Substantial increase in numbers of vulnerable people at risk
DT3.2 Prisons	Prisons, remand centres	Secure accommodation for those sentenced by court, or awaiting trial, etc. (Level 3)	Places providing detention Emergency action and evacuation may be very difficult

13.4 Development Type Table 4: Very Large and Sensitive Developments

Development Type	Examples	Development Detail and Size	Justification
Note: all Level 4 developments are by exception from Level 2 or 3 and are reproduced in this table for convenient reference			
DT4.1 Institutional Accommodation	Hospitals, convalescent homes, nursing homes, old people's homes, sheltered housing	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where 24-hour care is provided and where the site on the planning application being developed is larger than 0.25 hectare (Level 4)	Places providing an element of care or protection Because of age or state of health the occupants may be especially vulnerable to injury from hazardous events Emergency action and evacuation may be very difficult The risk to an individual may be small but there is a larger societal concern
	Nurseries, crèches, schools for children up to school leaving age	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where day care (not 24-hour care) is provided and where the site on the planning application being developed is larger than 1.4 hectare (Level 4)	Places providing an element of care or protection Because of the occupants that may be especially vulnerable to injury from hazardous events Emergency action and evacuation may be very difficult The risk to an individual may be small but there is a larger societal concern
DT4.2 Very Large Outdoor Use by Public	Theme parks, large sports stadia and events, open air markets, outdoor concerts, pop festivals	Predominantly open-air developments where there could be more than 1000 people present (Level 4)	People in the open air may be more exposed to toxic fumes and thermal radiation than if they were in buildings Large numbers make emergency action and evacuation difficult The risk to an individual may be small but there is a larger societal concern

14 APPENDIX C: DEPARTMENT OF EMPLOYMENT AND LABOUR CERTIFICATE

employment & labour

Department:
Employment and Labour
REPUBLIC OF SOUTH AFRICA

National Department of Employment and Labour
Republic of South Africa

APPROVED INSPECTION AUTHORITY

Registered in accordance with the provisions of the Occupational Health and Safety Act, Act 85 of 1993, as amended and the Major Hazard Installation Regulations.

THIS IS TO CERTIFY THAT:

RISCOM (PTY) LTD

has been registered by the Department of Employment and Labour as an Approved Inspection Authority: Type A, to conduct Major Hazard Installation Risk Assessment, in terms of Regulation 5(5)(a), of the Major Hazard Installation Regulations.

CONDITIONS OF REGISTRATION:

- *The AIA must at all time comply with the requirements of the Occupational Health and Safety Act, Act 85 of 1993, as amended.*
- *This registration certificate is not transferable.*
- *This registration will lapse if there is a name change of the AIA or change in ownership.*

CHIEF INSPECTOR

Valid from: 27 May 2021
Expires: 26 May 2025
Certificate Number: CI MHI 0005

15 APPENDIX D: SANAS CERTIFICATES

sanas
South African National Accreditation System

CERTIFICATE OF ACCREDITATION

In terms of section 22(2)(b) of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act, 2006 (Act 19 of 2006), read with sections 23(1), (2) and (3) of the said Act, I hereby certify that:-

RISCOM (PTY) LTD
Co. Reg. No.: 2002/019697/07
JOHANNESBURG

Accreditation Number: **MHI0013**

is a South African National Accreditation System Accredited Inspection Body to undertake **TYPE A** inspection provided that all SANAS conditions and requirements are complied with

This certificate is valid as per the scope as stated in the accompanying scope of accreditation, Annexure "A", bearing the above accreditation number for

THE ASSESSMENT OF RISK ON MAJOR HAZARD INSTALLATIONS

The facility is accredited in accordance with the recognised International Standard

ISO/IEC 17020:2012 AND SANS 1461:2018

The accreditation demonstrates technical competency for a defined scope and the operation of a management system

While this certificate remains valid, the Accredited Facility named above is authorised to use the relevant SANAS accreditation symbol to issue facility reports and/or certificates

Mr M Phaloane
Acting Chief Executive Officer

Effective Date: 27 May 2021
Certificate Expires: 26 May 2025

This certificate does not on its own confer authority to act as an Approved Inspection Authority as contemplated in the Major Hazard Installation Regulations. Approval to inspect within the regulatory domain is granted by the Department of Employment and Labour.

ANNEXURE A

SCOPE OF ACCREDITATION

Accreditation Number: MHI0013

TYPE A

Permanent Address: Riscom (Pty) Ltd 33 Brigish Dr Northcliff Johannesburg 2195 Tel: (011) 431-2198 Fax: 086 624-9423 Mobile: 082 457-3258 E-mail: mike@riscom.co.za	**Postal Address:** P O Box 2541 Cresta Johannesburg 2195 Issue No.: 17 Date of issue: 25 May 2021 Expiry date: 26 May 2025	
Nominated Representative: Mr MP Oberholzer	**Quality Manager:** Mr MP Oberholzer **Technical Manager:** Mr MP Oberholzer	**Technical Signatory:** Mr MP Oberholzer
Field of Inspection	**Service Rendered**	**Codes and Regulations**
Regulatory: The supply of services as an Inspection Authority for Major Hazard Risk Installation as defined in the Major Hazard Risk Installation Regulations, Government Notice No. R692 of 30 July 2001	Major Hazard Installation Risk Assessments for the following material categories: 1) Explosive chemicals 2) Gases: i) Flammable Gases ii) Non-flammable, non-toxic gases (asphyxiants) iii) Toxic gases 3) Flammable liquids 4) Flammable solids, substances liable to spontaneous combustion, substances that on contact with water release flammable gases 5) Oxidizing substances and organic peroxides 6) Toxic liquids and solids	MHI regulation par. **5 (5) (b)** i) Frequency/Probability Analysis ii) Consequence Modelling iii) Hazard Identification and Analysis iv) Emergency planning reviews Reference Manual Bevi Risk Assessments version 3.2 (2009) CPR 18E (1999), Guideline for quantitative risk assessment ("Purple Book"), TNO Apeldoorn. CPR 14E (1997). Methods for the Calculation of Physical Effects ("Yellow Book"), 3rd Edition, TNO, Apeldoorn. CPR 16E (1992). Methods for the Determination of Possible Damage ("Green Book"), 1st Edition, TNO, Apeldoorn. Lees FP (2001). Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control, 2nd Edition, Butterworths, London, UK.
Voluntary Supply of service as an inspection body for Hazard identification and analysis	Hazard identification and analysis including HAZARD of and operability studies (HAZOP)	SANS 1461 SANS 31000 SANS 31010

Original date of accreditation: 27 May 2005

Page 1 of 1

ISSUED BY THE SOUTH AFRICAN NATIONAL ACCREDITATION SYSTEM

Accreditation Manager

16 APPENDIX E: MATERIAL SAFETY DATA SHEETS

16.1 Ammonia

16.2 Diesel (Dodecane)

16.3 Hydrogen

16.4 Natural Gas