APPENDIX F11: Land Use Planning Risk Assessment

LAND USE PLANNING
RISK ASSESSMENT 2023
PROPOSED EXPANSION OF MOSSDUSTRIA & DEVELOPMENT OF A RACEWAY IN MOSSEL BAY

REPORT:	**LAND USE PLANNING RISK ASSESSMENT** **FOR THE PROPOSED EXPANSION OF MOSSDUSTRIA AND THE DEVELOPMENT OF A RACEWAY ADJACENT PETROSA IN MOSSEL BAY**
ASSIGNMENT NO:	J3215M
INSPECTION DATE:	25 April 2023
REPORT DATE:	29 August 2023
SITE VISIT, CALCULATIONS, REPORT: **Telephone:** **Email:**	Debra Mitchell 011 201 4783 mitchelld@ishecon.co.za
TECHNICAL SIGNATORY: **Telephone:** **Mobile phone:** **Email:**	Debra Mitchell 011 201 4783 082 428 8844 mitchelld@ishecon.co.za
CLIENT:	Gibb Environmental
INSTALLATION REPRESENTATIVE: **Phone:** **Email:**	Kate Flood 041 007 0040 / 084 631 1456 kflood@gibbenvironmental.co.za
PHYSICAL ADDRESS:	1st Floor, St Georges Corner, 116 Park Drive, Central Port Elizabeth 6001
POSTAL ADDRESS:	P O Box 63703, Greenacres, South Africa, 6057

ISHECON cc, H4 Pinelands Office Park, Maxwell Drive, Modderfontein, Box 320 Modderfontein 1645
Tel: (011) 201 4785 Fax: (086) 549 0878 Cell: (082) 428-8844
Email: mitchelld@ishecon.co.za
CK 99/29022/23 VAT 4800182422

iSHEcon
CHEMICAL PROCESS SAFETY ENGINEERS

REPORT ADMINISTRATIVE RECORD

LIST OF ASSESSMENTS

Assessment	Rev. No.	Report Date	Description
Preliminary Assessment		June 2022	Presentation of Preliminary QRA Results
Land Use Planning Quantitative Risk Assessment	1	29 August 2023	FINAL - LUP Risk Assessment for the Proposed Expansion of Mossdustria and Development of a Raceway Adjacent PetroSA in Mossel Bay - report issued by ISHECON.

CONTRIBUTORS

The validity, results and conclusions of this assessment are based on the expertise, skills and information provided by the following contributing team members who are responsible for the design, operation and maintenance of the plant and equipment:

NAME	ORGANISATION	DISCIPLINE
Carel Steyn	PetroSA	Operations Manager GTL Refinery (Acting)
Ross Murdoch	PetroSA	Process Optimization Manager
Kate Flood	Gibb Environmental	Senior Environmental Scientist

DISCLAIMER

Although every effort has been made by ISHECON to obtain the correct information and to carry out an appropriate, independent, impartial and competent study, it remains the facility's responsibility to ensure suitable Process Safety Measures are in place. ISHECON cannot be held liable for any accident or incident, due to negligence by the owner/operator, which directly or indirectly relates to the plant, equipment, facilities and systems analysed in this document and which may have an effect on the client or any other third party.

CONFIDENTIALITY

I*SHE*CON will keep all information, results and findings confidential, and will not pass these on to other parties without the permission of the Client. However, as an Approved Inspection Authorities for Department of Employment and Labour, I*SHE*CON is also under legal obligation to the Department of Employment and Labour to report any obvious violations of the OHS Act during site inspections.

RISK ASSESSMENT APPROVAL

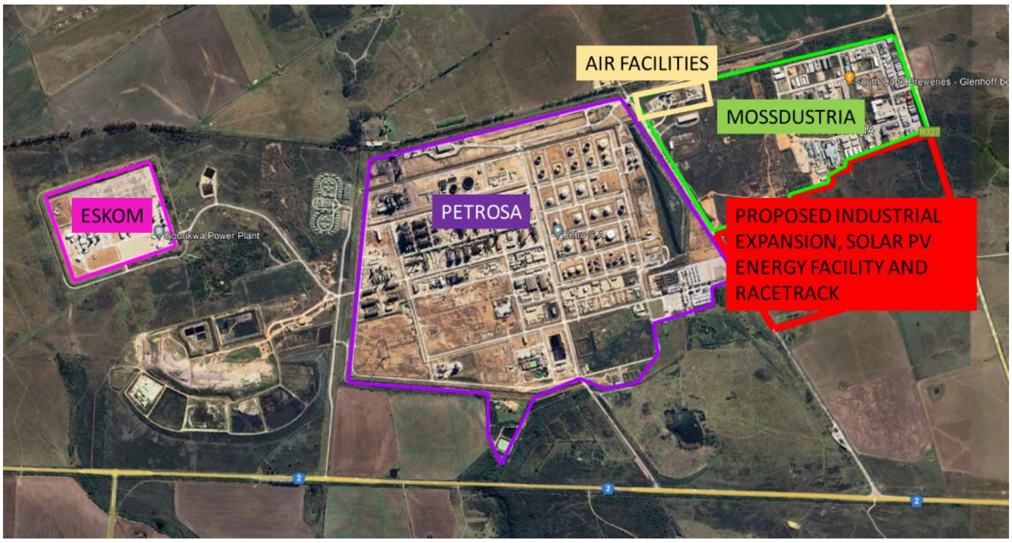
This report is approved for issue by the undersigned Technical Signatory as per the ISHECON.

NAME	CAPACITY	REPORT DATE	SIGNATURE
D.C. Mitchell	Site visit, Calculations Report preparation, Technical signatory:	29 August 2023	

EXECUTIVE SUMMARY

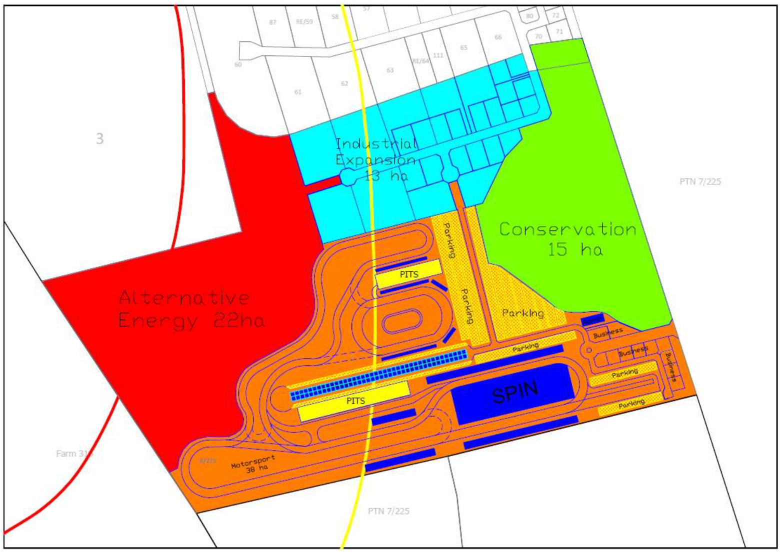
The developer, Mossel Bay Municipality in conjunction with a private 3rd Party, intends to expand the Mossdustria industrial area, erect a solar photovoltaic (PV) alternative energy facility and build a vehicle raceway / motorsport facility on open land adjacent the Mossdustria light industrial area and the PetroSA Gas to Liquid (GTL) Refinery complex just outside Mossel Bay in the Western Cape.

Aerial Photo of the Area showing the Various Developments



The development will have 13 ha for industrial, 22 ha for solar PV, 15 ha for a conservation area and the remained as a motorsports raceway facility. The motorsport facility will have various race tracks including pits, pavilions and viewing areas for public attending the races, an area for businesses/offices/eating facilities and parking lots etc.

Proposed layout of the Development



The proximity of the development to PetroSA has raised concerns about possible impacts on the area from accidents that may happen at PetroSA, e.g. fires, explosions or releases of toxic gases. For the purpose of guiding decision making, a Land Use Planning Risk Assessment has been requested. The risk assessment is to indicate the possible major accident impacts of PetroSA on the race track area and whether the likelihood of such events presents prohibitive risks for the race track development.

1. METHODOLOGY

Risk is made up of two components:
- The probability of a certain magnitude of hazardous event occurring.
- The severity of the consequences of the hazardous event.

This land-use planning risk assessment therefore includes the following:
- Identifying the likely major hazards expected to be associated with the operation of the PetroSA installation adjacent the proposed development, including the causes, consequences and effects.
- Quantifying the hazards in terms of their magnitude (release rate and duration).
- Quantifying the consequences of the hazards and the severity of the effects using dispersion, radiation and explosion modelling.
- Determining the lethality of the effects of the hazardous consequences.
- Quantifying the likely frequency of the hazardous events.
- Estimating the individual risks[1] by combining the severity (lethality) and the likelihood of the various hazards.
- Estimating the societal risk[2] by taking the surrounding population into account.
- Comparing risks with international acceptability criteria[3].
- Determining if the proposed development is compatible with Land-Use Planning guidelines.
- Highlighting and major uncertainties, assumptions and limitations of the study.

This land use planning risk assessment and report was conducted by an experience chemical engineer / risk assessor largely in compliance with the requirements of SANS 1461:2018: major Hazard Installation Quantitative Risk Assessment.

2. FINDINGS

Consequence Analysis

- The analysis found that the following are bulk hazardous materials present on the PetroSA site in sufficiently large quantities to possibly have offsite impacts should a major accident occur.

Bulk Hazardous Material	SANS10228 [Ref 2] Classification	Largest Vessel (t)
Methane (compressed natural gas, liquefied natural gas and biogas)	2.1 - Flammable gas	4 700
Liquefied gases (propane, propylene, butane, butylene, LPG)	2.1 - Flammable gas	1 200
Hydrogen fluoride	8 – Corrosive Liquid 6.1 Toxic liquid	20
Petrol	3.1 - Flammable liquid	6 000
Low flash point hydrocarbons (Condensate / naphtha / distillate etc)	3.1 - Flammable liquid	12 500
Diesel	3.1 - Flammable liquid	12 500

-

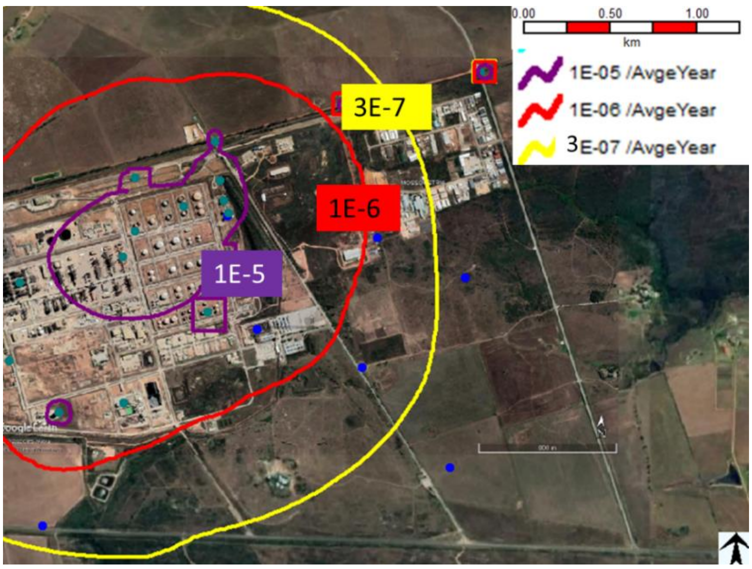
[1]The frequency at which an individual may be expected to sustain a given level of harm from the realisation of specified hazards.
[2] This is the relationship between the frequency and the number of people suffering from a specified level of harm in a given population from the realisation of specified hazards.
[3]A standard or a norm.

Based on the consequence analysis, done using SAFETI 8.61, the following are some of the possible offsite impacts:

MATERIAL	WORST-CASE INCIDENT*	DISTANCE OF SIGNIFICANT LETHAL EFFECTS (m)	MAJOR AFFECT ON THE DEVELOPMENT
Compressed natural gas	Pipeline rupture – delayed isolation – vapour cloud explosion (VCE)	145	No
Liquefied natural gas	Rupture of bulk tank – delayed vapour cloud explosion	800	Yes Western quarter
Biogas	Rupture of biogas system – vapour cloud explosion	100	No
Liquefied gases (Propylene)	Rupture of sphere – vapour cloud explosion	300	No
"	Boiling Liquid Expanding Vapour Explosion (BLEVE) of a sphere	1000	Yes Western half
"	Road/rail tanker loading hose rupture – 20 minutes isolation VCE	190	No
Petrol & Low flash point hydrocarbons	Rupture of tank – vapour cloud explosion	225	No
Hydrogen fluoride	Rupture of fresh acid holding tank – toxic gas cloud	1600	Yes
"	Large puncture of the reactor settler system – toxic gas cloud	2900	Yes

Risks

- Combining the above consequence modelling with the estimated likelihood of the events the following is a plot of the Individual Risk Isopleths for the area. These contours show the chance, in any one year, of a typical person outdoors in the area being fatally affected by any of the major accidents that could happen at PetroSA, i.e. the red contour is the one in a million chance per year of being fatally affected and is similar to ones chance of being struck by lightning.



(Purple= 1E-5 deaths/person/year, Red=1E-6, Yellow=3E-7)
Note: 1E-4 = 1 * 10^{-4} or 0.0001

- The above risk contours show that, from an existing industrial facility perspective, the unmitigated location specific individual risk levels posed by PetroSA over most of the area where the development is intended to be, can be considered broadly acceptable, i.e. less than one in million chance of death per person per year.

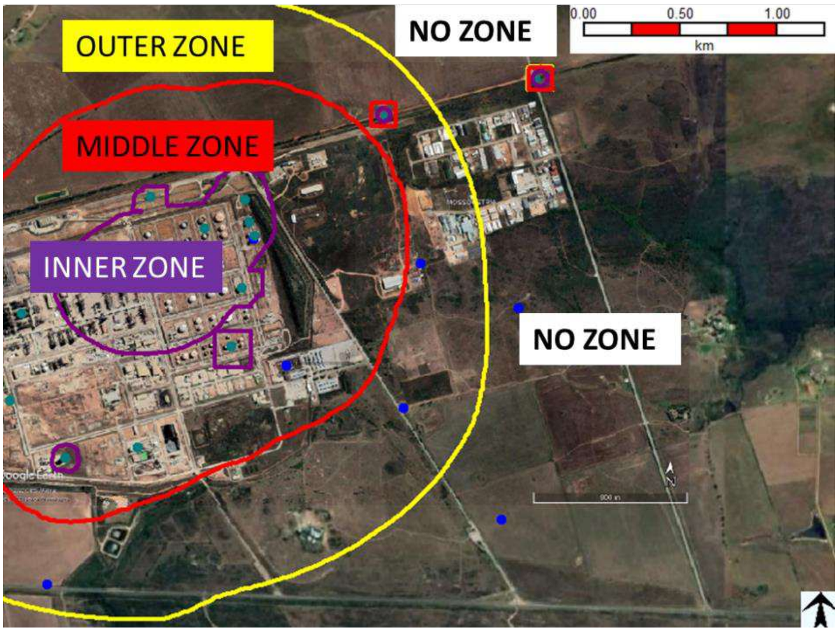
- Societal risks, i.e. the absolute number of person possibly affected by the range of accidental events, are tolerably low, provided PetroSA have done everything reasonably practicable to reduce the risks. The maximum number of fatalities for a worst-case scenario with PetroSA fully functional and the proposed development fully populated (i.e. 5 000 persons at the raceway), could be up to 1300 persons. The likelihood of this is less than once in 100 million years.

Land Use Planning

- There are no specific South African criteria that can be used to ensure suitable separation between developments. The United Kingdom's Health and Safety Executive (HSE) have been, for a number of years at the forefront of trying to establish a methodology to assist with land use planning close to hazardous Installation / Establishments. These UK HSE guidelines are usually applied in South Africa, and they are also referred to in the Major Hazard Installation Risk Assessment Standard SANS 1461.

- The HSE in the UK sets a consultation distance around major hazard sites and pipelines after assessing the risks and likely effects of major accidents at the Installation or pipeline. The Consultation Distance is comprised of three zones, these are designated as the Inner Zone (higher risk), the Middle Zone and the Outer Zone (lower risk). Developments within these zones require scrutiny. For this it is necessary to analyse the type of development being proposed near the industry. This is done by determining the sensitivity level of developments. The UK HSE have tables of typical developments and their suggested sensitivity levels.

- The figure below shows the estimated restricted risks zone in the PetroSA area.



- Based on the above risk zones and land-use planning concepts:
  - A Solar PV facility is not a highly populated facility and would be the least vulnerable type of development. There would be no human impact risk based restrictions on this develop, i.e. it could be located within any zone.
  - Small industrial facilities such as those currently in Mossdustria and the proposed expansion, i.e. less than 3 storeys high and with less than 100 persons per building, would only be restricted in the inner risk zone which does not even extend beyond the PetroSA site. There will therefore be no restrictions on industrial developments of any size in the middle and outer zones, i.e. in the proposed development area.
  - A large outdoor public facility such as the Motorsport Raceway would likely be considered a very vulnerable facility, i.e. of the most sensitive level. Such a development would not be advised within any of the risk zones, i.e. the development must be located beyond the risk restricted zones.
  - Based on the proposed layout of raceway, it is clear that the western section falls within the Outer Restricted Land-use zone. This section should be designed to ensure no public access and there are to be no public pavilions/gathering areas etc. planned in this area. The public areas will be on the eastern side of the raceway site, where there is no restricted zone.
  - If the pits areas have buildings within which pit staff can take shelter in the event of an emergency, then the pits can extend marginally into the outer zone. If they are purely outdoors then they too should be outside all the restricted zones.
  - The race tracks themselves can extend into the western outer zone as it is unlikely that there would be more than 100 race drivers in this area during an event.
  - Given societal risk impacts associated with the possible worst case events, it is advisable that the raceway events be restricted to 5 000 persons, i.e. not 10 000 persons.

Sensitivity

- The results of this assessment are sensitive to the process parameters and the modelling methods around the PetroSA hydrogen fluoride alkylation unit.
- The study assumes a PetroSA facility that is fully functional in a manner similar to that of full production a few years ago.

Emergency Plan

- All facilities in the Mossdustria area, but particularly the motorsport raceway, are advised to have an Emergency Response Plan (including necessary facilities) in place and to link the plan to the PetroSA Emergency Response Plan.
- The plan should be practiced regularly, e.g. small, localized drills quarterly and one large evacuation type dill annually. For the latter, even if one does not actually evacuate the public, practice setting up the systems on a very busy race weekend so that all role players know what they would do in the event of an actual emergency. The full evacuation can be physically practiced on a less busy day.

3. RECOMMENDATIONS

The following recommendations have been made:

1. Based on the proposed layout of Mossdustria expansion development (i.e. public persons in the eastern section and western sections being restricted non-public areas) and its location relative to the Land-Use Planning restricted risk zones around PetroSA (i.e. western section within the outer zone and eastern section not within any zone), there is no risk-based justification to advise against the development although some facilities may need to be shifted slightly eastwards. Furthermore, it is suggested that the maximum number of public persons at large events at the raceway be restricted to 5 000 at any one time.

2. As the area where development is to be located is not entirely without risks from PetroSA (i.e. possible impacts from major accidents at the Liquefied Natural Gas tank (LNG), Liquefied Petroleum Gas spheres (LPG) or the HF alkylation unit), all facilities within the development, especially the motorsport raceway facility, should have an Emergency Response Plan and related facilities in place. The plans for each development should link to the PetroSA site and its Emergency Response Plan. The plans should be practiced regularly, e.g. small, localized drills quarterly and one large evacuation type dill annually. For the latter at the raceway development, even if one does not actually evacuate the public, the owner/operator should practice setting up the systems on a very busy race weekend so that all role players know what they would do in the event of an actual emergency. The full evacuation can be physically practiced on a less busy day.

3. Given the sensitivity of these land use planning zones to the Petro SA HF alkylation unit, should the unit be re-commissioned at some stage in the future, it is advised that the loading of fresh HF into the holding tank as well as the initial start-up of the reactor-settler unit be co-ordinated with raceway such that the recommissioning does NOT take place at the same time as any racing events with large numbers (i.e. more than 100) persons present at the raceway.

TABLE OF CONTENTS

APPENDICES

GLOSSARY OF SOME TERMS USED IN THIS REPORT

List of units, acronyms and abbreviations used in this report	Definition
AIA	Approved Inspection Authority
ALARP	As Low As Reasonably Practicable
ASOV	Automated Shut-Off Valve
CAS number	A unique numerical identifier assigned by the Chemical Abstracts Service (CAS) to every chemical substance described in the open scientific literature
d/p/y	Deaths per persons per year
EFV	Excess Flow Valve
EIA	Environmental Impact Assessment
ERPG	Emergency Response Planning Guideline
E-stop	Emergency stop button
F-N curve	Frequency of N+ fatalities curve (graph)
G-room	Gas escape room
GMR	General Machinery Regulations
GTL	Gas To Liquid
H/HH/HHH	High/High high/High high high, usually referring to operating parameters e.g. temperature/pressure
HAZOP	Hazard and Operability Study
IBC	Intermediate Bulk Container, usually 1000 litre capacity
kW	Kilowatts
kPa	Kilopascal
m	Metres
m^2	Metres squared
m^3	Metres cubed
MHI	Major Hazard Installation
ppm	Parts Per Million (volume basis)
PRV	Pressure Relief Valve
(Q)RA	(Quantitative) Risk Assessment
ROSOV	Remotely Operated Shut-Off Valve
SANS	South African National Standards
SDS	Safety Data Sheet
SOP	Standard (Safe) Operating Procedure
XV	On/Off valve, usually operated by a solenoid when linked to an E-stop

1. INTRODUCTION

1.1 SCOPE OF ASSESSMENT

The developer, Mossel Bay Municipality in conjunction with a private 3rd Party, intends to expand the Mossdustria industrial area, erect an alternative energy facility and build a vehicle raceway / motorsport facility on open land adjacent the Mossdustria light industrial area and the PetroSA Gas to Liquid (GTL) Refinery complex just outside Mossel Bay in the Western Cape.

The development will have 13 ha for industrial, 22 ha for solar PV, 15 ha for a conservation area and the remained as a motorsports raceway facility. The motorsport facility will have various race tracks including pits, pavilions and viewing areas for public attending the races, an area for businesses/offices/eating facilities and parking lots etc

The proximity of the development to PetroSA has raised concerns about possible impacts on the area from accidents that may happen at PetroSA, e.g. fires, explosions or releases of toxic gases. For the purpose of guiding decision making, a Land Use Planning Risk Assessment has been requested. The risk assessment is to indicate the possible major accident impacts of PetroSA on the race track area and whether the likelihood of such events presents prohibitive risks for the race track development.

Several sections of the report necessitate substantiating information, which can be found in the appendices. The structure of the report is such that the numbering of the appendix will correspond with the numbering of the relevant section in the body of the report. Thus, should one want to look up further information regarding the weather data in section 2.2, the appendix with the corresponding information will be numbered as Appendix 2.2.

Although this assessment is based on the best available information and expertise, ISHECON cc cannot be held liable for any incident that may occur at the PetroSA installation and industries in Mossdustria that has an impact over the race track area and which directly or indirectly relates to the work in this report.

1.2 SCOPE OF APPLICATION

This risk assessment is not a Major Hazard Installation (MHI) risk assessment for either PetroSA or any other industry in the area. However, in the absence of such a risk assessment being provided by PetroSA or other industries in the area, this land use planning risk assessment was conducted on a similar basis to provide the local authority with guidance on possible accident impacts so that they can fulfil their requirements and comply with the Major Hazard Installation Regulations under the (Occupational Health and Safety Act Nr. 85 of 1993, revised January 2022).

1.3 PHILOSOPHY FOR CLASSIFICATION AS AN MHI

For installations which fall within the jurisdiction of the OHS Act (e.g. not necessarily for those that fall under the Mine Health and Safety Act or under the Merchant Shipping Act etc.), two criteria define a site as an MHI:

1.	Under the 2022 MHI Regulations ANNEXURE A contains a list of hazardous materials with qualifying quantities for each. Under the 2001 MHI Regulations, the General Machinery Regulations* contained this list. A site that stores more than the prescribed quantity of any of these materials is classified as an MHI. Under the new regulations there are three quantity thresholds for low, medium and high hazard installations.

OR

2.	An installation that could cause a major incident that will affect the public is also classified as an MHI. MHI risk assessments consider only sites with materials that could lead to catastrophic fires, explosions or toxic releases.

If PetroSA were within the jurisdiction of the OHS Act it would be classified as a High Hazard Establishment under the MHI Regulations of 2022.

*(of the Occupational Health and Safety Act Nr. 85 of 1993)

1.4 RISK ASSESSMENT METHODOLOGY

Risk is made up of two components:

- The probability of a certain hazardous event or incident occurring.
- The severity of the consequences of that hazardous event / incident.

Therefore, this assessment of risk comprises:

- Identification of the likely hazards and major hazardous events related to the operation of the installations adjacent the proposed race track development.
- Calculation of the likelihood of these hazardous events occurring,
- Calculation of the consequences of these hazardous events.
- Estimation of the risk and comparison against certain acceptability criteria.
- Evaluation of the proposed development in relation to risk restricted land use zones.

Refer to Appendix 1.4 for details.

Competencies:

- There are no competencies specified for conducting a Land Use Planning Risk Assessment. However, since this study is related to industries which pose major hazards, it would be prudent to apply similar competency requirements to the MHI regulations.
- The MHI regulations require that a risk assessment should be carried out by a Department of Labour Approved Inspection Authority (AIA) to comply with the South African standard SANS 1461.2018 Edition 1.
- Refer to Appendix 1.4 for details of competency.

2. DESCRIPTIONS

2.1 PROPOSED DEVELOPMENT AND SURROUNDING AREAS

2.1.1 DEVELOPMENT

The development will have 22 ha for a solar PV facility and this area will not be for public access. There will also be a 15 ha conservation area with limited public access. Immediately adjacent the current Mossdustria area, 12- 13 ha will be set aside for light industrial development. The remainder of the development, located mostly the south eastern section of the development area, will be for a motorsports raceway facility. The motorsport facility will have various race tracks including pits, pavilions and viewing areas for public attending the races, an area for businesses/offices/eating facilities and parking lots etc.

Parking areas, offices, pavilions and public viewing areas will be restricted to the eastern section of the site, with only the race tracks themselves extending toward the western side adjacent PetroSA.

2.1.2 LOCATION AND PHYSICAL ADDRESS

The installation's physical address is:

Remainder of Portion 8 of the Farm Rietvalley 225 GPS co-ordinates: 34°10'02.65"S, 22°00'19.66"E

2.1.3 DESCRIPTION OF SITE AND SURROUNDINGS

On **Figure 2.1.2** the border of the proposed development site is marked in RED.

The following nearby locations are relevant:

1. Neighbouring industrial sites:
   a. Mossdustria immediately to the north – various light industries.
2. Nearby MHIs and possible MHIs:
   a. The PetroSA facility immediately to the west.
   b. Air Products/Afrox/Air Liquide facilities approximately 1km to the north west.
3. Residential areas:
   a. No suburban or informal residential areas. There are a few isolated farmsteads in the area.
4. Busy main roads or highways:
   a. N2 – approximately 1km to the south.
5. Schools or hospitals:
   a. None.
6. Other:
   a. Agricultural land.

Figure 2.1.1 is a map of South Africa showing the location of site.
Figure 2.1.2 shows the location of the site and surrounding area in more detail.
Figure 2.1.3 is a layout of the proposed development site.

Figure 2.1.1 - Map showing the location of the Proposed Development Site

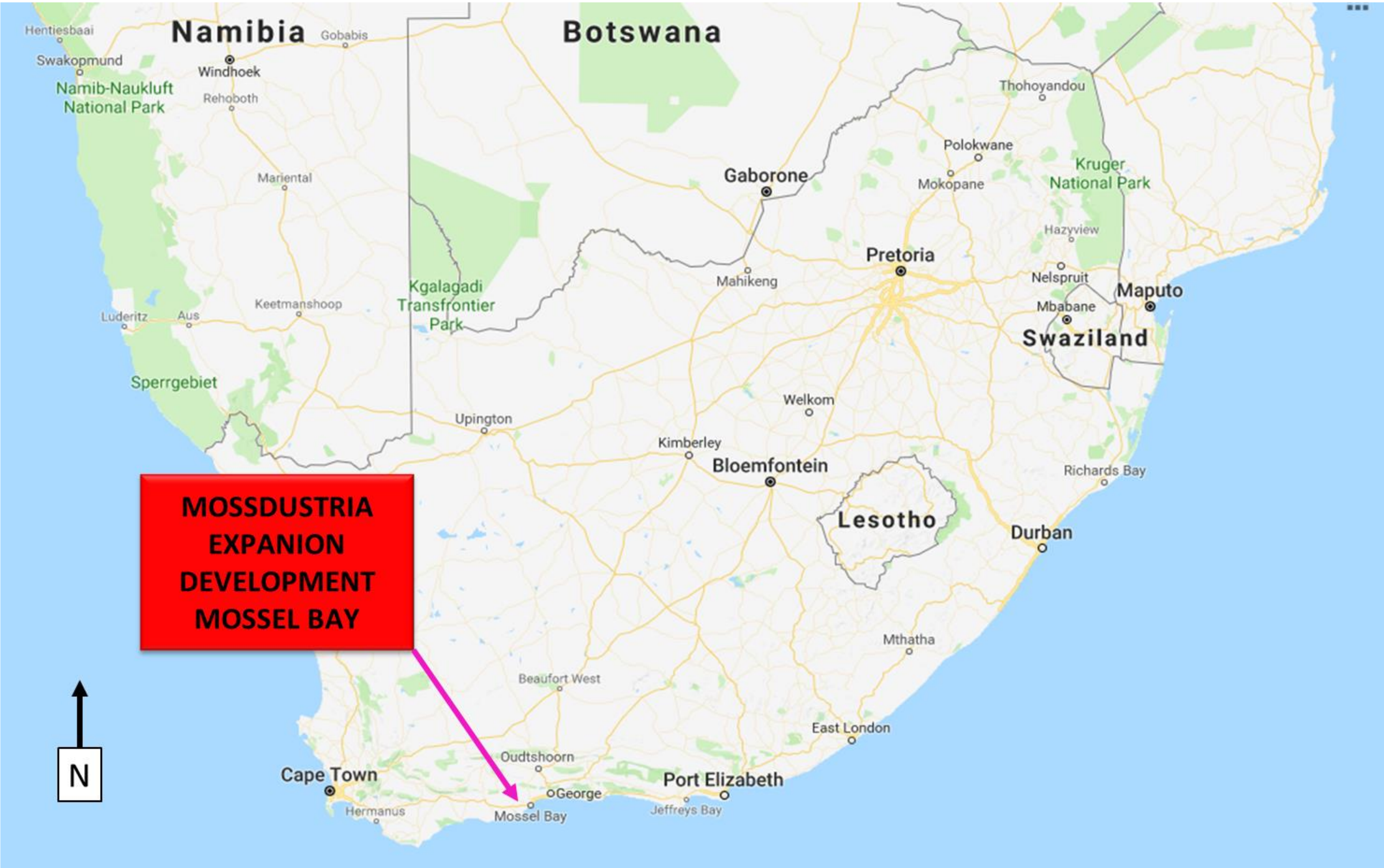


Figure 2.1.2 - The location of the site and surrounding area

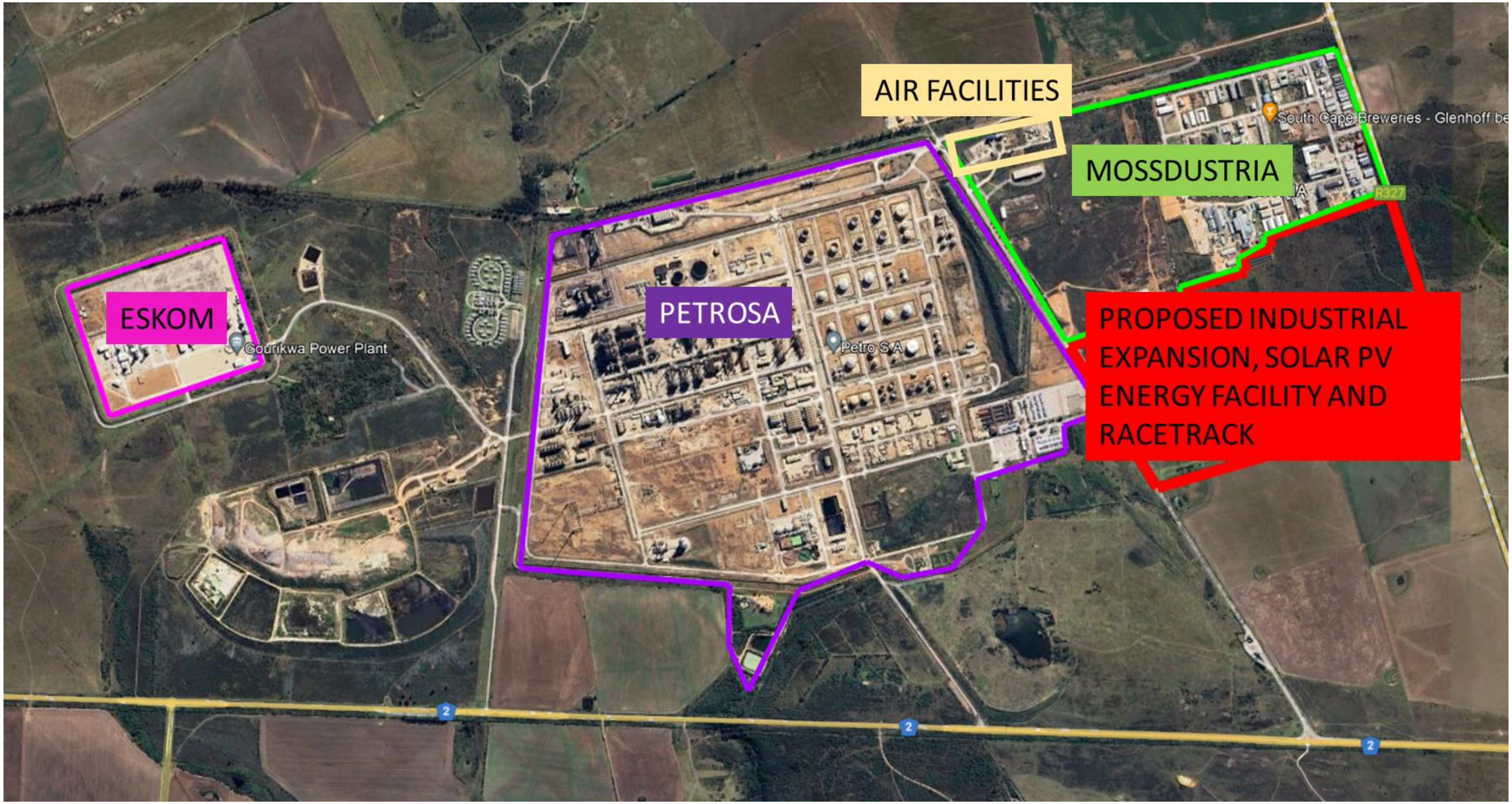
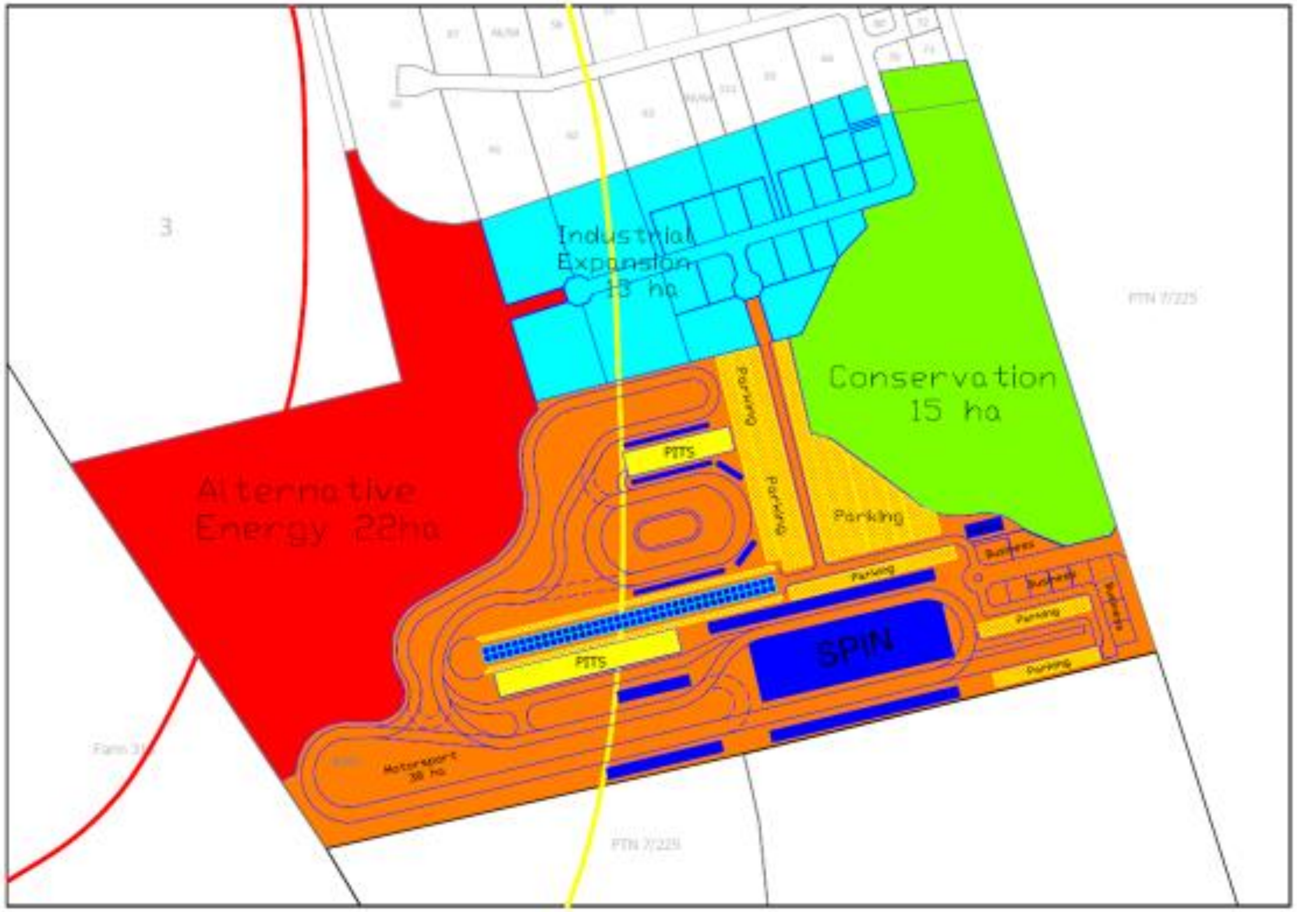


Figure 2.1.3 is a layout of the development site showing the main facilities (Solar PV, Industrial and Raceway)



2.2 TOPOGRAPHY AND METEOROLOGY

2.2.1 TOPOGRAPHY

The area surrounding the facility is flat with small hills 2km to the north and the sea over 4km to the south.

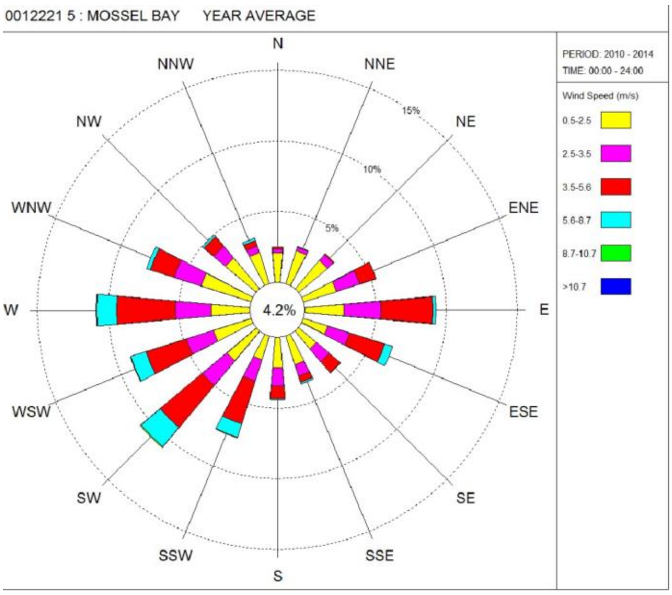
The risk assessment software (SAFETI 8.61) does not take into account topography such as hills and valleys, nor local thermal conditions (upward currents due to heat generated by industries). However, the surrounding land is classified according to its “surface roughness” which influences dispersion modelling. (Refer to Appendix 2.2).

Across South Africa seismic activity is conceivable with Gauteng (man-made activity) the Western Cape (natural activity) being relatively higher risk areas. However, compared with aspects such as corrosion, human error etc. seismic activity is not usually a highly likely MHI risk factor, refer to SANS 10160:2011, part 4.

2.2.2 METEOROLOGY

Weather data for Mossel Bay was applied to the site.

Figure 2.2.2 Mossel Bay wind rose:



The dominant wind directions are from the west and south west, with the easterly wind also blowing a fair amount of the time. This means that releases of toxic or flammable materials at PetroSA (mostly on the northern side of the PetroSA site) should most often blow towards Mossdustria and not towards the southern area where the race track is to be located.. (Refer to Appendix 2.2).

Across South Africa, lightning strikes are conceivable as a source of ignition of major hazards, refer to SANS10313:2012 lightning strike density table. However, generally ignition from on-plant sources is much more likely than lightning and the frequency data need therefore not be specifically adjusted.

2.3 PLANT AND PROCESSES

The descriptions below are relevant to the PetroSA plant and not the race track.

2.3.1 DESCRIPTION

The PetroSA facility is located about 10 km to the west of Mossel Bay. The site has been in operation since the late 1980's early 1990's. The facility takes natural gas and condensate from an off-shore rig and converts it to Synfuels.

Natural gas and condensate from the off-shore rig are transferred by pipeline into the gas to liquid conversion facility. The 16-18" pipeline is mostly underground and comes above ground only when well within the factory perimeter. Excess gas can be liquefied and stored as a buffer in the liquefied natural gas (LNG) facility. The first processing step is to remove the propane and butane from the gas, leaving a methane risk stream for liquid fuel production. To produce fuel there is an oxygen plant, three methane gas to liquid reactors (with catalyst), gas separation and clean up, methane reforming etc. This is followed by a refining facility which includes an alkylation plant. The alkylation plant uses hydrofluoric acid (HF) which dominates the offsite risk profile of PetroSA. However, PetroSA is in the process of removing all HF from the site until the facility is possibly recommissioned at some stage in the future.

Within the GTL site is a large tank farm, Unit 51, providing buffer storage for the various product. Materials can be pumped from these storage tanks to other tanks within the site, loaded into road/rail trucks or exported via long underground pipelines to the tanks at Voorbaai for transfer out to ship. There are numerous tanks (up to 12.5Ml each) that contains low flash petroleum liquids.

It is also possible to import liquids onto the site. Liquid are imported / pumped up from the on shore depot/pumping station at Voorbaai. Outside the factory the pipelines are buried but within the factory pipelines are above ground on pipe racks.

The liquid fuels storage tanks are designed, manufactured and installed to API standards as well as any local applicable standards. Fire systems is designed to NFPA standards. The diesel and slops tank are fixed roof and the condensate, reformate and petrol are floating roof tanks. The tanks are fully bunded with a bunded capacity that can hold 110% of the largest tank.

.

In addition, in Unit 51 are four large (2 Ml) liquefied gas spheres, three LPG blending bullets and facilities for loading LPG into road or rail tankers. These pressurized storage vessels dominate the hazard and the risk profiles in the existing tank farm and the Mossdustria area.

In the north western corner of Mossdustria are two oxygen/nitrogen facilities that take excess gases from the Petro SA site and use them commercially.

2.3.2 STAFF AND SHIFT ARRANGEMENT

PetroSA is currently running a very reduced operation due to unavailability of gas. The facility would normally operate 24/7 with three separate shifts. The site is strictly access controlled. In full production there could be up to 2500 employees on the site during the day and 500 at night. At present the number are about 20% of these numbers.

Most of the business within Mossdustria only operate during the day with relatively low occupancy, assumed < 300 persons.

The raceway will have racing events mostly at the weekends during the day and early evening. The numbers of public person at the events are expected to be:

- Weekly events - 500 - 1,000
- Monthly - 1,000 - 2,000
- Large events (1-3 per year) - 5,000 - 10,000

For this assessment it is assumed that there would not be more than 5000 persons at the largest public events.

3. HAZARD IDENTIFICATION

3.1 MATERIAL HAZARDS

3.1.1 HAZARDOUS MATERIALS ON THE SITE

The materials on the site were categorised according to SANS 10228 classes of dangerous substances, as detailed below in Table 3.1. A determination was made whether these materials could constitute a major hazard risk over the Mossdustria area that needed to be quantified further, refer to following sections.

Table 3.1: Summary of key hazardous material inventories

	CAS number	SANS10228 [Ref 2] Classification	Maximum Inventory (t)	Largest Vessel (t)	Potential Offsite Impacts
Methane (compressed natural gas, liquefied natural gas and biogas)	74-82-8	2.1 - Flammable gas	5 000	4 700	Yes
Liquefied gases (propane, propylene, butane, butylene, LPG)	68476-85-7	2.1 - Flammable gas	5 600	1 200	Yes
Hydrogen fluoride	7664-39-3	8 – Corrosive Liquid 6.1 Toxic liquid	20 +15=35	20	Yes
Petrol	64742-48-9	3.1 - Flammable liquid	30 000	6 000	Possibly
Low flash point hydrocarbons (Condensate / naphtha / distillate etc)	68919-39-1 8032-32-4	3.1 - Flammable liquid	50 000	8 000	Possibly
Diesel	68476-34-6	3.1 - Flammable liquid	76 000	12 500	No

Note - the above is not an exhaustive list of all materials on the PetroSA site, merely those in sufficiently large quantities to be expected to have offsite impacts over the Mossdustria area should the worst case accidents materialize.

3.1.2 ENVIRONMENTAL HAZARDS

Assessment of environmental impacts is not included in this risk assessment, as it should be addressed in an Environmental Impact Assessment for the site. Environmental hazards associated with the operations on this site should be addressed in an Environmental Management Programme.

3.1.3 HAZARDOUS MATERIAL INTERACTIONS

Some hazardous chemicals, when mixed, may result in flammable, explosive or toxic effects. There are no expected interactions that would have worse effects that the releases of LPG and hydrogen fluoride already included in this assessment. Effects of inadvertent mixing would likely be limited to onsite impacts.

3.2 PAST ACCIDENTS AND INCIDENTS RELEVANT TO MAJOR HAZARDS

3.2.1 SITE

There was a major explosion at the methane reforming facility in the early 2000s, but impacts were limited to within the PetroSA site. There have been some overflows of tanks in the PetroSA tank farm and there was one tank collapse due to blockage of the vent valve. There have been some incidents on the PetroSA processing plant but no major events in the tank farms. There have been no major hot work related explosions or fires on the existing tanks. There have been a few pipeline failures but none that have led to ignitions.

There have been no events that have impacted on public persons outside the PetroSA site, specifically no impacts in the proposed development area

3.2.2 OTHER FACILITIES LOCAL AND INTERNATIONAL

Significant hazardous events have occurred at other similar or related installations around the world or with the type materials that are used on site. Some of these include:

- Buncefield UK Dec 2005 – overfilling of petrol tank being feed via pipeline. Formation of a vapour cloud, ignition and severe explosion damage followed by sustained fire in the tank depot area. No fatalities but severe off site damage up to half a kilometre from the site.
- Mexico City 1985 – pipeline failure releasing LPG gas, vapour cloud ignited by the flare, jet fire impinging on bulk LPG sphere, BLEVE of initial sphere followed by BLEVEs of other spheres, tanks etc. More than 600 fatalities and severe off site damage.
- Cleveland USA 1944 – LNG tank failure, vapour cloud, explosion, secondary tank failure. 131 fatalities and one square mile destroyed.
- Gumi South Korea 2012 – 8 tons of hydrogen fluoride was released from a road tanker offloading on a site. 5 fatalities on site, 4195 treated for injuries, evacuation 1.5 km radius.
- Philadelphia USA 2019 – 1.5 tons of hydrogen fluoride released for the HF Alkylation unit due to failure of a corroded pipe. In addition to fires and explosions from hydrocarbon released simultaneously, there was a toxic exposure element due to the HF. Five on site injuries, no offsite effects.

4. HAZARD ANALYSIS

The table below lists the incidents that were considered in this study as well as key process parameters. A ROSOV is a remotely operated shut off valve that an operator can activate to isolate a leak from the process (typically a pipeline and leaks directly on a vessel cannot be easily isolated), usually within 5 minutes. Operator Emergency Isolation (OEI) requires an operator to be present near the operation (typically when loading/offloading road/rail tankers) and who is able to isolate almost immediately, i.e. within 2 minutes. In the absence of rapid shutting systems, it is assumed that an operator/supervisor will take at least 20 minutes to manually isolate the system, or it cannot be isolated and is assumed to continue releasing material for at least an hour.

Table 4.1 – Scenarios

SCENARIO NAME	MASS INVENTORY (kg)	TEMPERATURE (deg Celsius)	HOLE SIZE (mm)	FREQUENCY
TANK FARM AREA				
1. Propane Sphere Catastrophic rupture	986000	23	0	4.00E-05
2. Propane Sphere Large liquid puncture	986000	23	100	4.00E-05
3. Propane Sphere Large vapour puncture	986000	23	150	4.00E-05
4. Propane Sphere Small liquid puncture	986000	23	10	8.00E-04
5. Propane Sphere PSV fails open	986000	23	52	8.00E-04
6. Propane Sphere Internal explosion (TNT equivalent)				8.00E-05
7. Propylene Sphere Catastrophic rupture	1026000	23	0	4.00E-05
8. Propylene Sphere Large liquid puncture	1026000	23	100	4.00E-05
9. Propylene Sphere Large vapour puncture	1026000	23	150	4.00E-05
10. Propylene Sphere Small liquid puncture	1026000	23	10	8.00E-04
11. Propylene Sphere PSV fails open	1026000	23	52	8.00E-04
12. Propylene Sphere Internal explosion (TNT equivalent)				8.00E-05
13. Butane Sphere Catastrophic rupture	1146000	23	0	4.00E-05
14. Butane Sphere Large liquid puncture	1146000	23	100	4.00E-05
15. Butane Sphere Large vapour puncture	1146000	23	150	4.00E-05
16. Butane Sphere Small liquid puncture	1146000	23	10	8.00E-04

SCENARIO NAME	MASS INVENTORY (kg)	TEMPERATURE (deg Celsius)	HOLE SIZE (mm)	FREQUENCY
17. Butane Sphere PSV fails open	1146000	23	52	8.00E-04
18. Butane Sphere Internal explosion (TNT equivalent)				8.00E-05
19. Butylene Sphere Catastrophic rupture	1240000	23	0	4.00E-05
20. Butylene Sphere Large liquid puncture	1240000	23	100	4.00E-05
21. Butylene Sphere Large vapour puncture	1240000	23	150	4.00E-05
22. Butylene Sphere Small liquid puncture	1240000	23	10	8.00E-04
23. Butylene Sphere PSV fails open	1240000	23	52	8.00E-04
24. Butylene Sphere Internal explosion (TNT equivalent)				8.00E-05
25. LPG Bullets Catastrophic rupture	182325	23	0	1.20E-04
26. LPG Bullets Large liquid puncture	182325	23	100	1.20E-04
27. LPG Bullets Large vapour puncture	182325	23	150	1.20E-04
28. LPG Bullets Small liquid puncture	182325	23	10	2.40E-03
29. LPG Bullets PSV fails open	182325	23	52	2.40E-03
30. LPG Bullets Internal explosion (TNT equivalent)				2.40E-04
31. LPG Transfer pipe Line rupture Isolated 5 minutes (ROSOV) 300	182325	23	100	3.60E-03
32. LPG Transfer pipe Line rupture Isolated supervisor 20 mins 1200	182325	23	100	4.00E-04
33. LPG Transfer pipe Line leak Isolated 5 minutes (ROSOV) 300	182325	23	10	1.80E-02
34. LPG Transfer pipe Line leak Isolated supervisor 20 mins 1200	182325	23	10	2.00E-03
35. LPG Loading hose Line rupture Isolated 2 minutes (OEI) 120	182325	23	50	4.29E-06
36. LPG Loading hose Line rupture Isolated supervisor 20 mins 1200	182325	23	50	4.76E-07
37. LPG Loading hose Line leak Isolated 2 minutes (OEI) 120	182325	23	5	2.14E-05
38. LPG Loading hose Line leak Isolated supervisor 20 mins 1200	182325	23	5	2.38E-06
39. LPG Road or rail tanker Catastrophic rupture	30000	23	0	2.38E-05
40. LPG Road or rail tanker Large liquid puncture	30000	23	50	2.38E-05
41. LPG Road or rail tanker Large vapour puncture	30000	23	100	2.38E-05
42. LPG Road or rail tanker Small liquid puncture	30000	23	10	4.76E-04
43. LPG Road or rail tanker PSV fails open	30000	23	32	4.76E-04

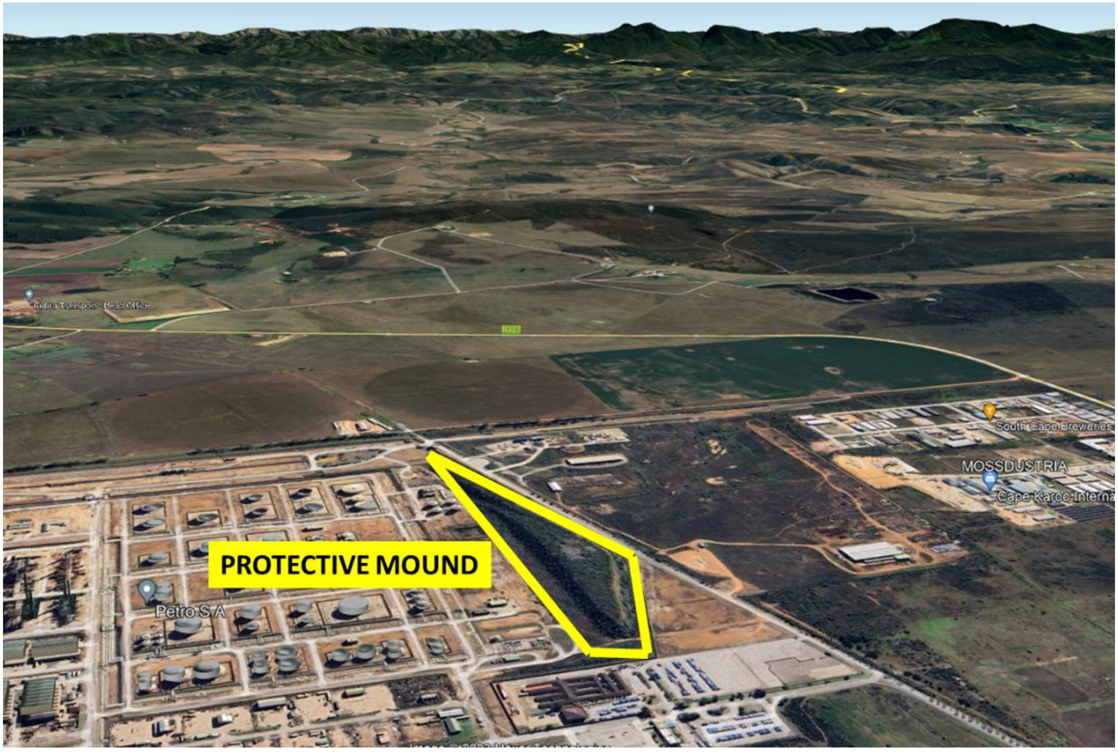
SCENARIO NAME	MASS INVENTORY (kg)	TEMPERATURE (deg Celsius)	HOLE SIZE (mm)	FREQUENCY
44. LPG Road or rail tanker Internal explosion (TNT equivalent)				4.76E-05
45. Low flash Tanks north Catastrophic rupture	6400000	23	0	2.80E-04
46. Low flash Tanks north Large puncture	6400000	23	250	2.80E-04
47. Low flash Tanks north Small puncture	6400000	23	10	5.60E-03
48. Low flash Tanks north Overfill	6400000	23	250	1.14E+00
49. Low flash Tanks north Internal explosion (TNT equivalent)				5.60E-04
50. Low flash Tank east Catastrophic rupture	6400000	23	0	4.00E-05
51. Low flash Tank east Large puncture	6400000	23	250	4.00E-05
52. Low flash Tank east Small puncture	6400000	23	10	8.00E-04
53. Low flash Tank east Overfill	6400000	23	250	1.63E-01
54. Low flash Tank east Internal explosion (TNT equivalent)				8.00E-05
55. Low flash Tanks south Catastrophic rupture	6400000	23	0	2.40E-04
56. Low flash Tanks south Large puncture	6400000	23	250	2.40E-04
57. Low flash Tanks south Small puncture	6400000	23	10	4.80E-03
58. Low flash Tanks south Overfill	6400000	23	250	9.77E-01
59. Low flash Tanks south Internal explosion (TNT equivalent)				4.80E-04
RAIL/ROAD TANKER FILLING AREA				
60. Low flash Transfer pipe Line rupture Isolated 5 minutes (ROSOV) 300	6400000	23	250	7.20E-03
61. Low flash Transfer pipe Line rupture Isolated supervisor 20 mins 1200	6400000	23	250	8.00E-04
62. Low flash Transfer pipe Line leak Isolated 5 minutes (ROSOV) 300	6400000	23	25	3.60E-02
63. Low flash Transfer pipe Line leak Isolated supervisor 20 mins 1200	6400000	23	25	4.00E-03
64. Low flash Rail filling hose Rupture Isolated 2 minutes (OEI) 120	6400000	23	50	1.24E-01
65. Low flash Rail filling hose Rupture Isolated supervisor 20 mins 1200	6400000	23	50	1.38E-02
66. Low flash Rail filling hose Leak Isolated 2 minutes (OEI) 120	6400000	23	5	1.24E+00
67. Low flash Rail filling hose Leak Isolated supervisor 20 mins 1200	6400000	23	5	1.38E-01
68. Low flash Rail tanker Catastrophic rupture	40000	23	0	3.95E-05
69. Low flash Rail tanker Large puncture	40000	23	50	1.97E-06

SCENARIO NAME	MASS INVENTORY (kg)	TEMPERATURE (deg Celsius)	HOLE SIZE (mm)	FREQUENCY
70. Low flash Rail tanker Small puncture	40000	23	5	3.95E-04
PROCESSING AREA (REFINERY)				
71. Low flash COD recycle drum Catastrophic rupture	99820	106	0	8.00E-05
72. Low flash COD recycle drum Large puncture	99820	106	100	4.00E-06
73. Low flash COD recycle drum Small puncture	99820	106	10	8.00E-04
83. HF Holding tank Catastrophic rupture	20000	23	0	4.00E-06
84. HF Holding tank Large puncture	20000	23	50	3.20E-06
85. HF Holding tank Small puncture	20000	23	10	8.00E-05
86. HF Alky-reactor settler system Catastrophic rupture	85000	40	0	4.00E-05
87. HF Alky-reactor settler system Large puncture	85000	40	250	3.20E-05
88. HF Alky-reactor settler system Small puncture emergency dump 20 minutes	15000	40	10	8.00E-04
86a & 87a. HF Circulation pipe Rupture isolated 5 minutes (ROSOV) and not isolated (similar due to speed at which contents are released < 60 s))	15000	23	250	8.00E-06
88a. HF Transfer pipe Leak Isolated 5 minutes (ROSOV) 300	15000	23	10	3.60E-05
89a. HF Transfer pipe Leak	15000	23	10	4.00E-06
PIPELINES LEAVING THE COMPLEX ADJACENT MOSSDUSTRIA				
71. Low flash Cross country pipeline (Moss west) Rupture Isolated 20 minutes 1200	6400000	23	250	7.20E-04
72. Low flash Cross country pipeline (Moss west) Rupture	6400000	23	250	8.00E-05
73. Low flash Cross country pipeline (Moss west) Leak Isolated 20 minutes 1200	6400000	23	25	3.60E-03
74. Low flash Cross country pipeline (Moss west) Leak	6400000	23	25	4.00E-04
75. Low flash Cross country pipeline (Moss cent) Rupture Isolated 20 minutes 1200	6400000	23	250	7.20E-04
76. Low flash Cross country pipeline (Moss cent) Rupture	6400000	23	250	8.00E-05
77. Low flash Cross country pipeline (Moss cent) Leak Isolated 20 minutes 1200	6400000	23	25	3.60E-03
78. Low flash Cross country pipeline (Moss cent) Leak	6400000	23	25	4.00E-04
79. Low flash Cross country pipeline (Moss east) Rupture Isolated 20 minutes 1200	6400000	23	250	7.20E-04
80. Low flash Cross country pipeline (Moss east) Rupture	6400000	23	250	8.00E-05
81. Low flash Cross country pipeline (Moss east) Leak Isolated 20 minutes 1200	6400000	23	25	3.60E-03

SCENARIO NAME	MASS INVENTORY (kg)	TEMPERATURE (deg Celsius)	HOLE SIZE (mm)	FREQUENCY
82. Low flash Cross country pipeline (Moss east) Leak	6400000	23	25	4.00E-04
GAS FROM THE OFFSHORE RIG AND LNG				
91. LNG Storage tank Rupture Outer protective wall	4223000	23		4.00E-06
92. LNG Storage tank Large liq puncture Outer protective wall	4223000	23	400	4.00E-06
93. LNG Storage tank Small liq puncture Outer protective wall	4223000	23	10	8.00E-05
94. LNG Outlet line Rupture ROSOV 5 min isolation 300	4223000	23	400	7.92E-07
95. LNG Outlet line Rupture	4223000	23	400	8.00E-09
96. Natural Gas Supply from offshore Rupture 20 min isolation 1200	40000	23	450	3.60E-05
97. Natural Gas Supply from offshore Rupture	40000	23	450	4.00E-06
98. Natural Gas Supply to LNG Rupture 20 min isolation 1200	40000	23	400	3.60E-04
99. Natural Gas Supply to LNG Rupture	40000	23	400	4.00E-05
EFFLUENT PLANT				
100. Biogas Digester Rupture	612	50		1.20E-04
101. Biogas Digester Large puncture	612	50	400	1.20E-04
102. Biogas Digester Small puncture	612	50	10	2.40E-03
103. Biogas Digester Outlet rupture	612	50	400	4.00E-03

5. CONSEQUENCE ANALYSIS

One of the important features of the Petro SA plant is a large protective mound of earth over two stories high located between the tank farm storage area and the Mossdustria area, see image below. This mound will serve to shield Mossdustria (and the proposed expansion) from the worst effects of any accidental explosions and fires in the tank farm area. The modelling used in this study does NOT take credit for this protective mound, it assumes the land is open and flat. In this manner the very worst case radiation and explosion effects are shown, i.e. the risk model is conservative. In the case of an HF release, it is possible that the mound may divert vapours away from the Mossdustria area, but again it is assumed that this does not happen and the model is conservative.



Below are the consequence modelling results for the worst-case event for each material and selected additional events (*information on all incidents can be made available on request).*

Refer to the tables in the Appendix 5 in order to interpret the impact (damage) from the contours below.

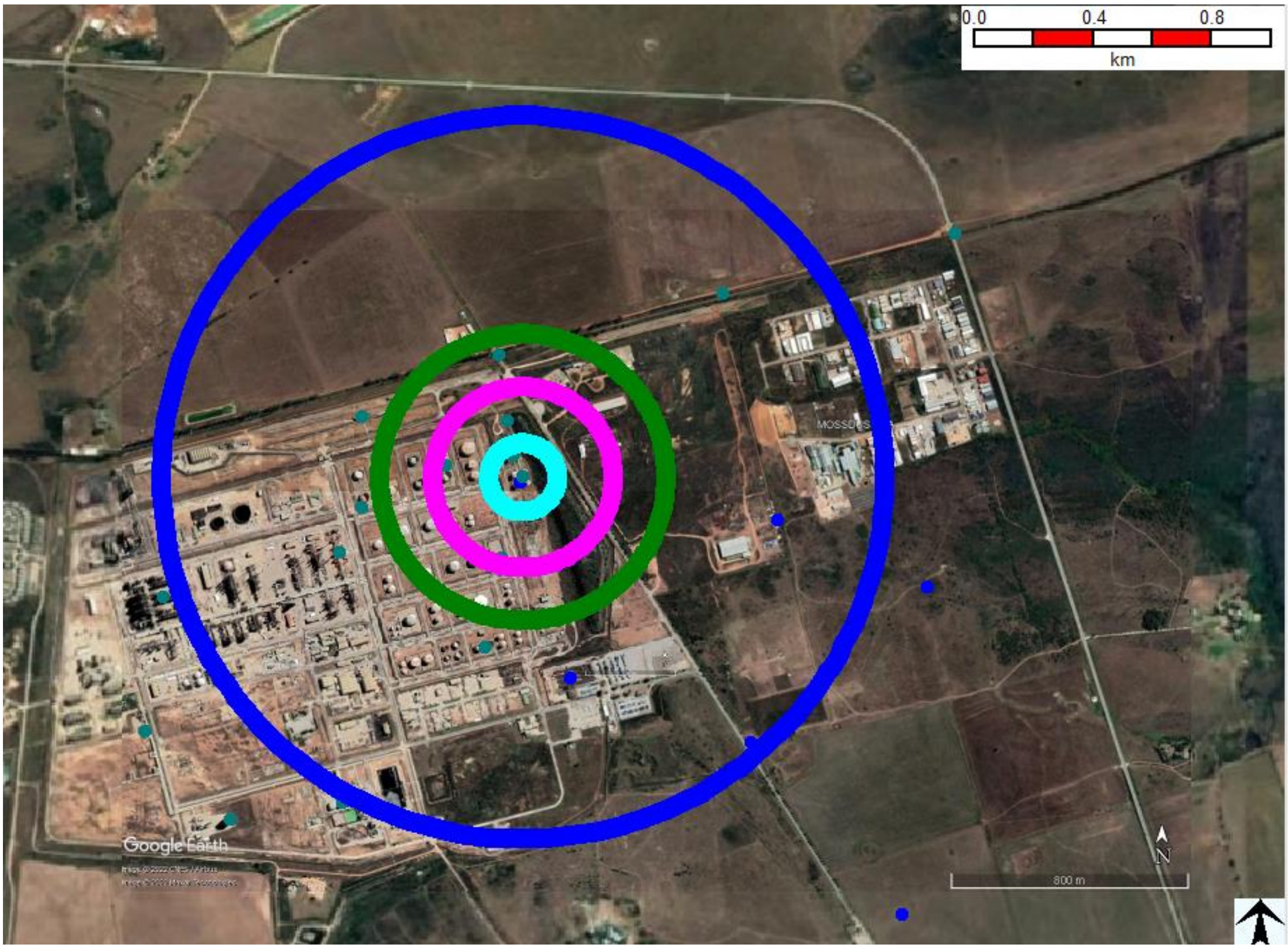
5.1 FLAMMABLE EVENTS - EXPLOSIONS

5.1.1 LPG STORAGE SPHERES AND ROAD /RAIL LOADING

The plot below shows that over the area of the proposed development an explosion from the rupture of one of the large LPG spheres (very unlikely) should not lead to severe damage or large numbers of fatalities. The damage should be limited to windows cracked, sheeting blown off, flimsy structures bent and impact from small fragments of metal that move like missiles.

Figure 5.1.1 Propylene Sphere rupture – overpressure circles from explosion
Large bold circles show maximum extent in any wind direction.

- Dark blue = 2kPa – windows cracked shrapnel missiles, no direct fatalities (1.2km radius)
- Green = 7 kPa – slight structural damage, 0.1% lethality (450 m radius)
- Pink = 14kPa – structural damage to standard buildings, 1% lethality (300 m radius)
- Light blue = 70kPa – severe destruction, possible domino failure of other equipment, >90% lethality (120 m radius)



Note the dots are not relevant to this report. They relate the technical model, with light blue dots are point sources of releases, and dark blue specific locations where risk ranking results were estimated.

The plot below shows that an explosion from the rupture of one of the LPG truck road or rail filling hoses (more likely than rupture of the pressure vessels themselves) should not have any significant impacts over the area of the proposed development.

Figure 5.1.1.2 LPG loading hose rupture with release isolated within 20 minutes – overpressure circles (delayed explosion)

Large bold circles show maximum extent in any wind direction.

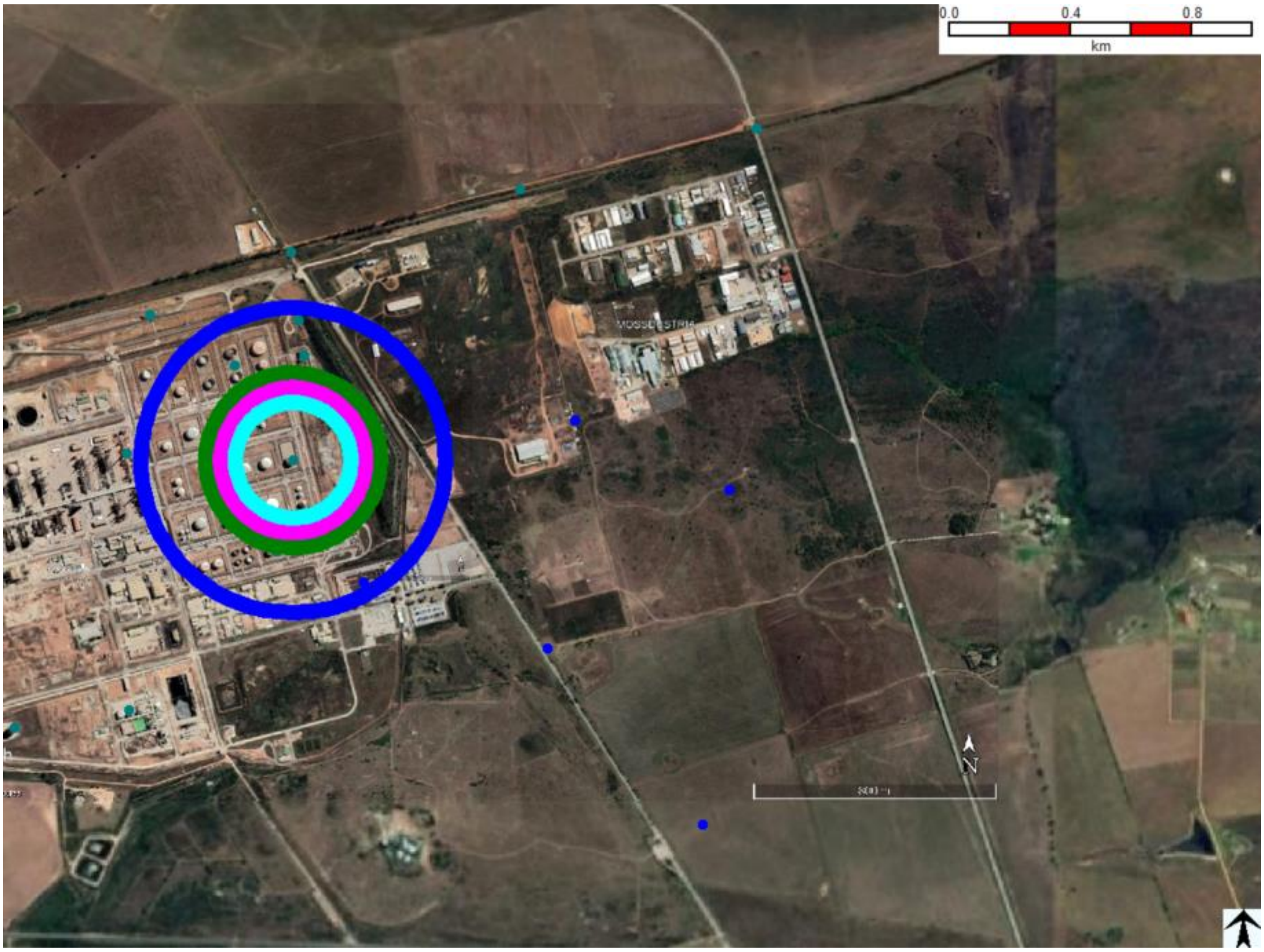
- Blue = 2kPa – maximum extent of windows cracked shrapnel missiles, no direct fatalities 300m radius
- Green = 7 kPa – slight structural damage, 0.1% lethality (210 m radius)
- Pink = 14kPa – structural damage to standard buildings, 1% lethality (190 m radius)
- Light blue = 70kPa – severe destruction, possible domino failure of other equipment, >90% lethality (175 m radius)

5.1.2 LOW FLASH LIQUID (PETROL) STORAGE TANKS

The plot below shows that over the area of the proposed development an explosion from the rupture of one of the large low flash point liquid fuel tanks (very unlikely) should not lead to severe damage or large numbers of fatalities.

Figure 5.1.2.1 Rupture of a large petrol storage tank – overpressure circles (delayed explosion)
Large bold circles show maximum extent in any wind direction.

- Dark blue = 2kPa – maximum extent of windows cracked shrapnel missiles, no direct fatalities 500m radius
- Green = 7 kPa – slight structural damage, 0.1% lethality (275 m radius)
- Pink = 14kPa – structural damage to standard buildings, 1% lethality (225 m radius)
- Light blue = 70kPa – severe destruction, possible domino failure of other equipment, >90% lethality (195 m radius)



5.1.3 NATURAL GAS / LNG / BIOGAS

Natural gas is liquefied and stored at just above atmospheric pressure and about -160 deg C.

Figure 5.1.3.1 LNG bulk tank rupture – overpressure circles from explosion
Large bold circles show maximum extent in any wind direction. Small circles are actual explosion for a north-westerly wind.

- Dark blue = 2kPa – windows cracked, shrapnel missiles, no direct fatalities (1.8m radius)
- Green = 7 kPa – slight structural damage, 0.1% lethality (1000 m radius)
- Pink = 14kPa – structural damage to standard buildings, 1% lethality (800 m radius)
- Light blue = 70kPa – severe destruction, possible domino failure of other equipment, >90% lethality (650 m radius)

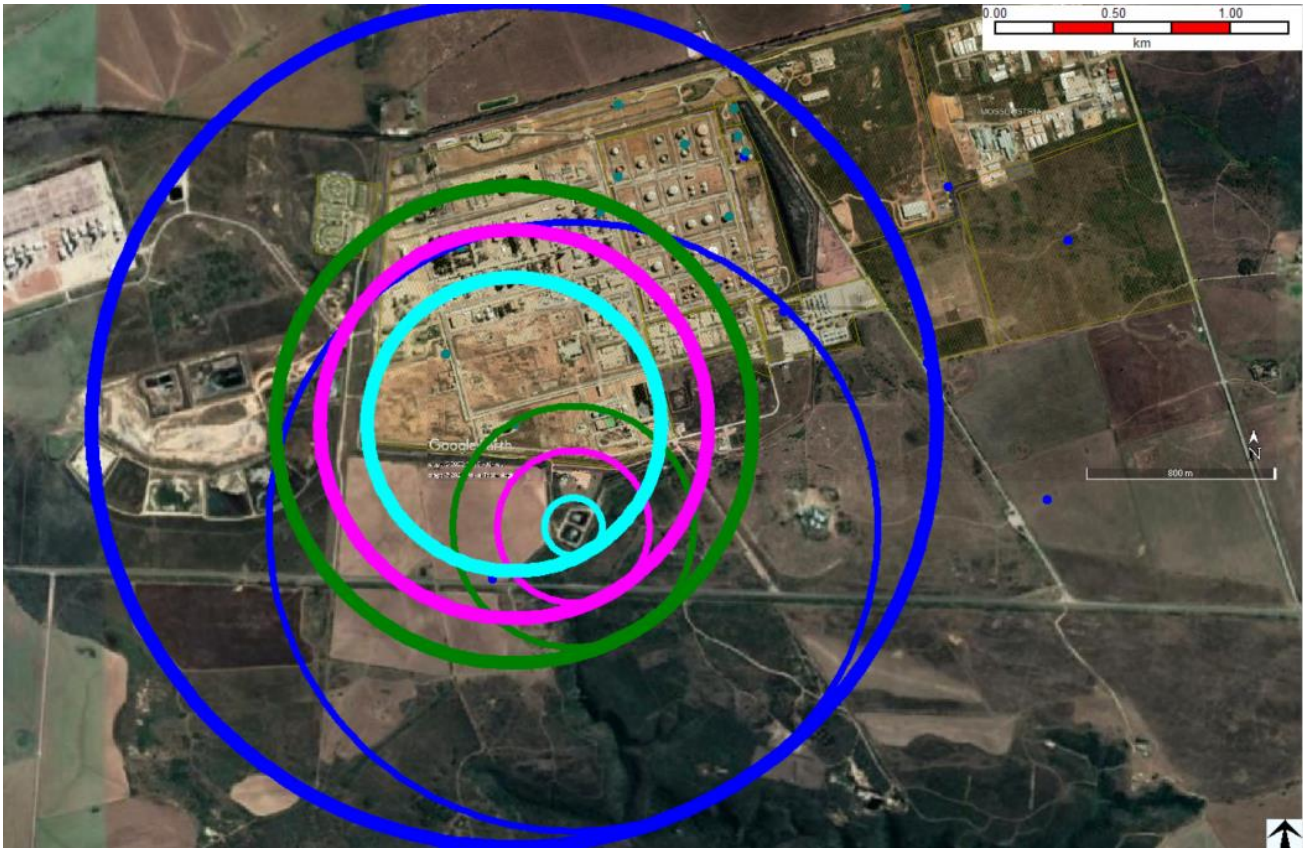
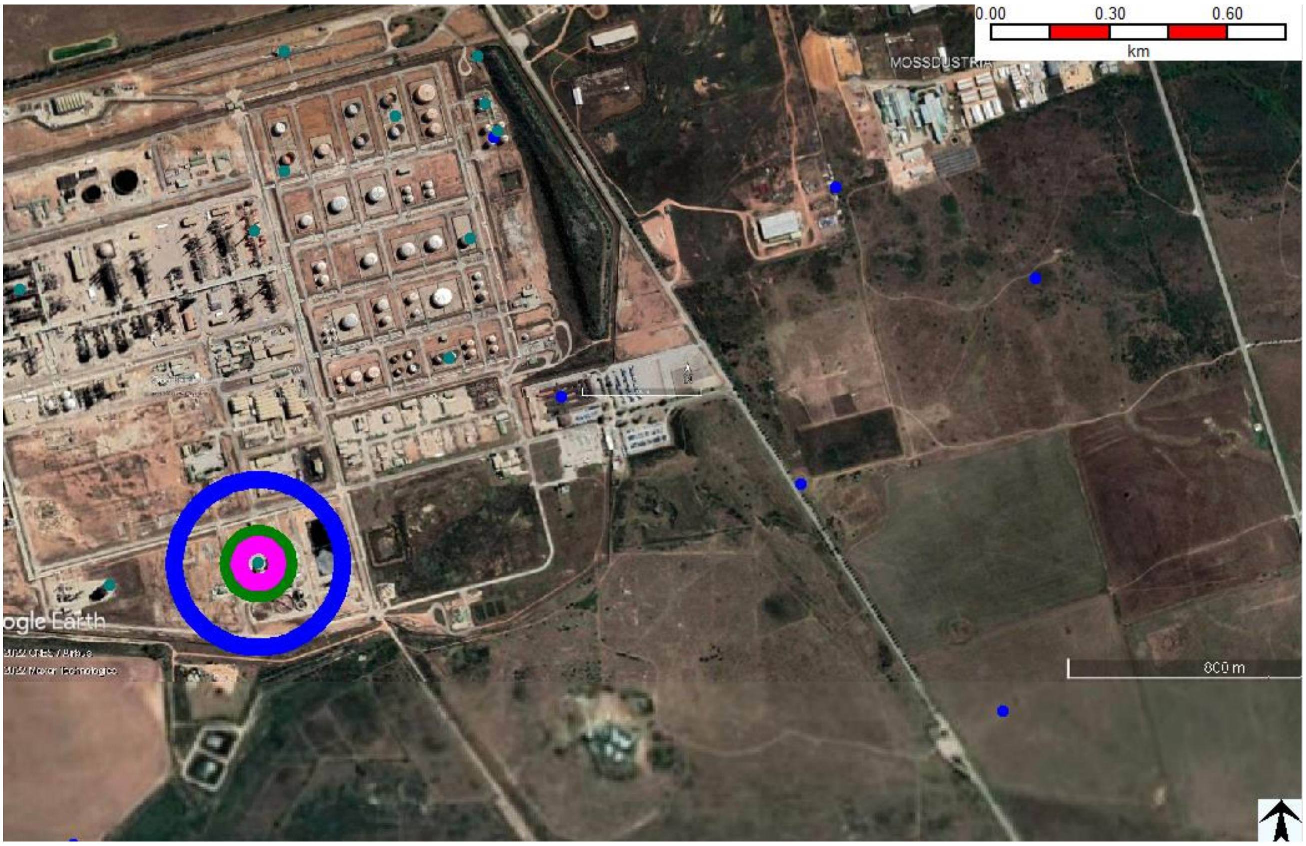


Figure 5.1.3.2 High pressure natural gas supply to plant - pipe rupture – explosion

- Dark blue = 2kPa – windows cracked shrapnel missiles, no direct fatalities (340m radius)
- Green = 7 kPa – slight structural damage, 0.1% lethality (180 m radius)
- Pink = 14kPa – structural damage to standard buildings, 1% lethality (145 m radius)
- Light blue = 70kPa – severe destruction, possible domino failure of other equipment, >90% lethality (120 m radius)
- Depending on the degree of congestion (i.e. lots of equipment) around the point of release, this event could generate pressure higher than 1 bar resulting in much greater levels of destruction within 100m.

Figure 5.1.3.3 Anaerobic Effluent Treatment System rupture – Biogas explosion

- Dark blue = 2kPa – windows cracked shrapnel missiles, no direct fatalities (onsite only)
- Green = 7 kPa – slight structural damage, 0.1% lethality (onsite only)
- Pink = 14kPa – structural damage to standard buildings, 1% lethality (onsite only)

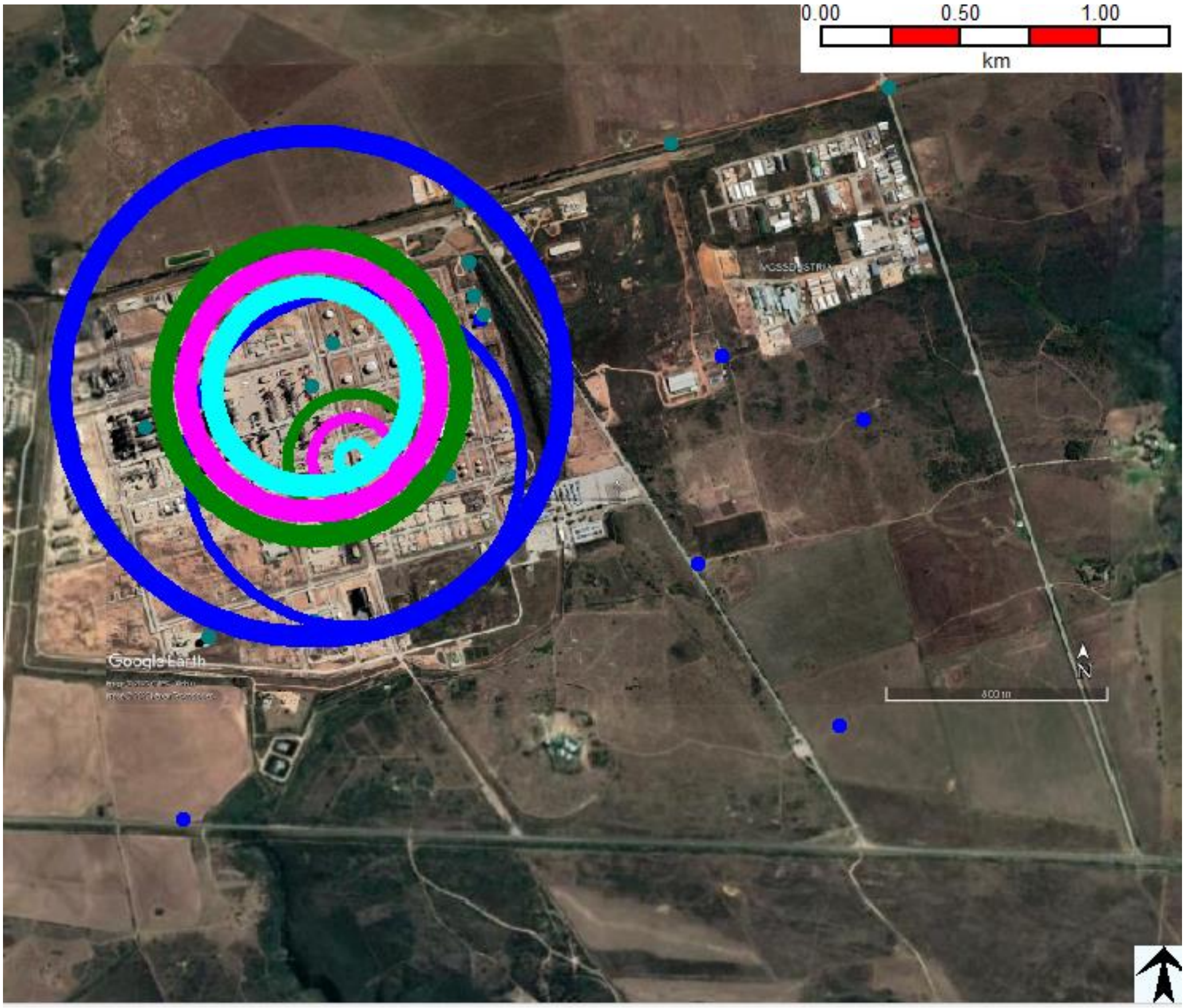


5.1.4 HF ALKYLATION UNIT

Refer to section 5.3 below for a description of the HF Alkylation unit. The plot below is for the effects of the hydrocarbon phase (e.g. isobutane).

Figure 5.1.4.1 HF alkylation reactor settler system catastrophic rupture – hydrocarbon phase explosion

- Dark blue = 2kPa – windows cracked shrapnel missiles, no direct fatalities (900m)
- Green = 7 kPa – slight structural damage, 0.1% lethality (750m)
- Pink = 14kPa – structural damage to standard buildings, 1% lethality (onsite only)
- Light blue = 70kPa – severe destruction, possible domino failure of other equipment, >90% lethality (onsite only)

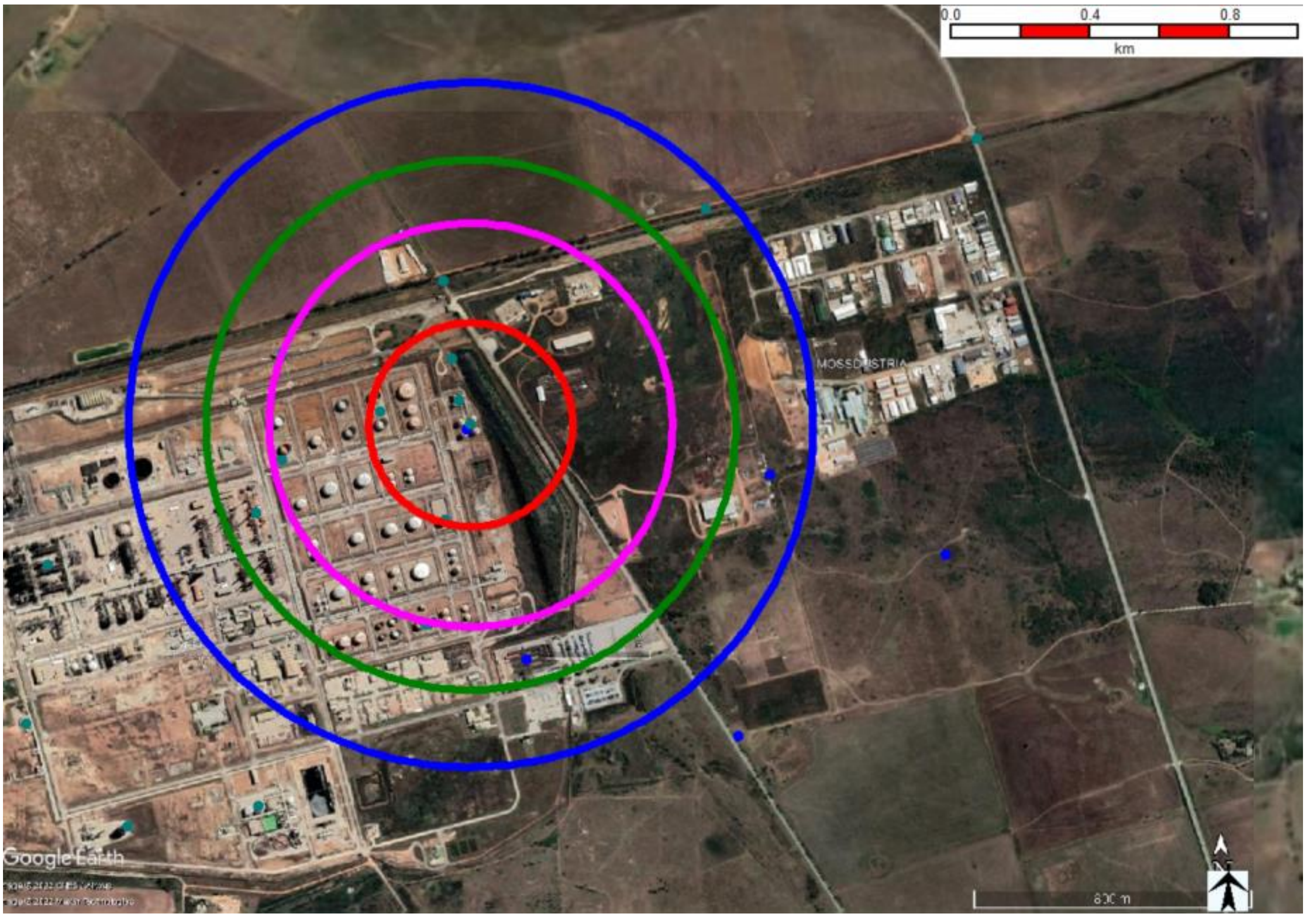


5.2 FLAMMABLE EVENTS - FIRES

5.2.1 LPG STORAGE SPHERE BLEVE

Figure 5.2.1.1 BLEVE of a Propylene / Propane / Butane / Butylene Sphere

- Dark blue = 1% lethal (1000m)
- Green = 25% lethal (750m)
- Pink = 80% lethal (600m)
- Red = 100% lethal (300m)



5.3 TOXIC EVENTS

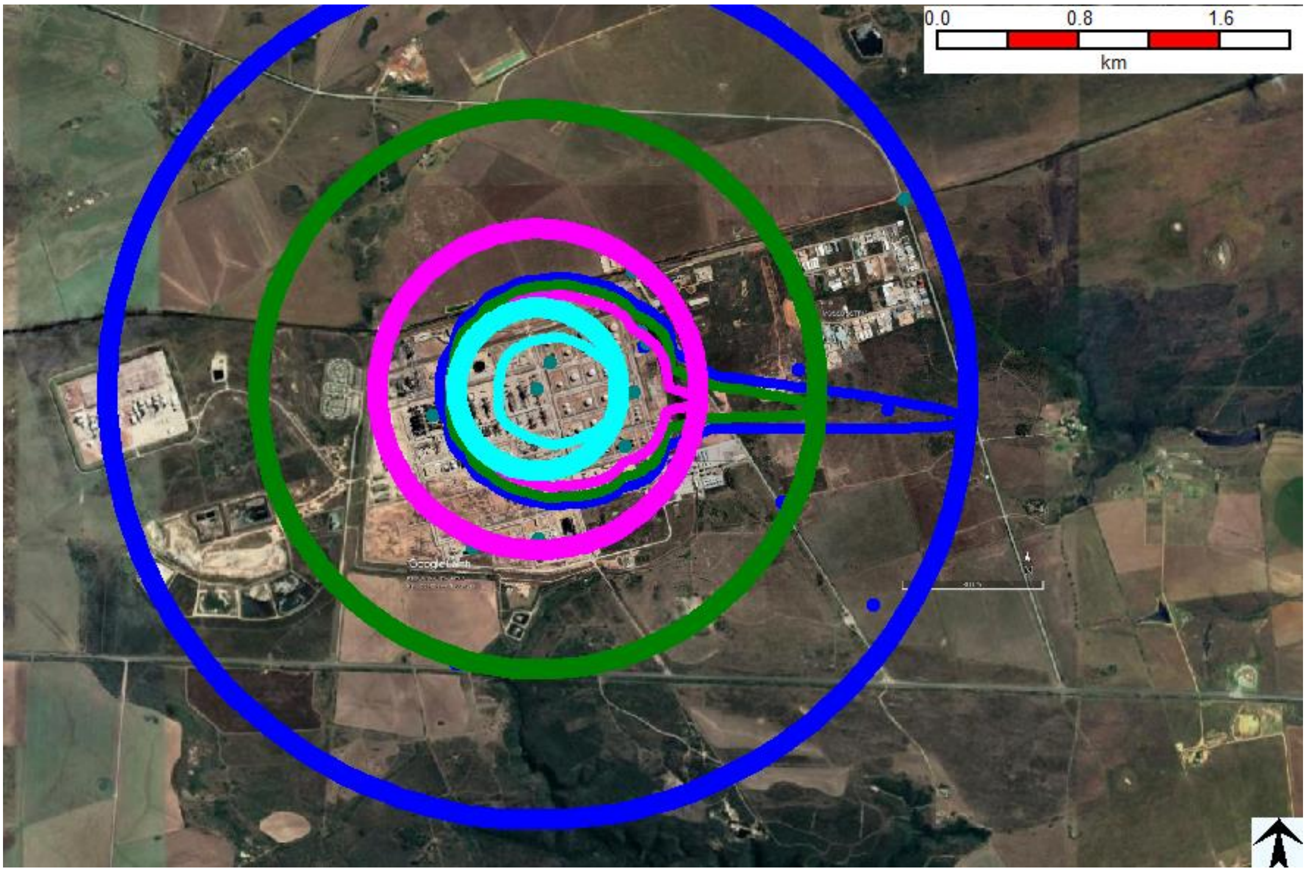
5.3.1 HYDROFLUORIC ACID

Anhydrous hydrofluoric acid (HF) is used only in one small section of the plant. There is a 20t fresh acid holding tank (ambient conditions) that can be refilled from road tanker, but this has not happened in the last ten years and is unlikely to happen unless the entire PetroSA facility is recommissioned for full production. From the holding tank a small amount of acid can be made up to the reactor-settler circuit to compensate for slight inefficiencies. Acid is added to the reactor where it is mixed with hydrocarbons under slightly elevated temperature and pressure. From here the reacted mixture flows into a settler where the acid and hydrocarbon phases separate. The acid phase is recirculated to back to the reactor and the hydrocarbon phase is routed to residual acid removal and then further processing. There is an emergency dump system where the acid phase can be dumped from the settler should there be a leak in the system. At present, as a risk reduction exercise, any HF remaining in the system is being removed from the site for safe disposal.

5.3.1.1 Map showing outdoor toxic lethality plumes for rupture of the HF holding tank – fresh acid

Bold circles show maximum extent in any wind direction. Faint plume is actual toxic cloud for night time weather conditions with a north-westerly wind.

- Blue = 0.1% lethality – 2400m downwind within the plume
- Green = 1% Lethality effect zone – 1600 m radius within the plume
- Pink = 10% lethal 900 m radius within the plume
- Light blue – 100% lethal – 440m within the plume which can be 600m wide

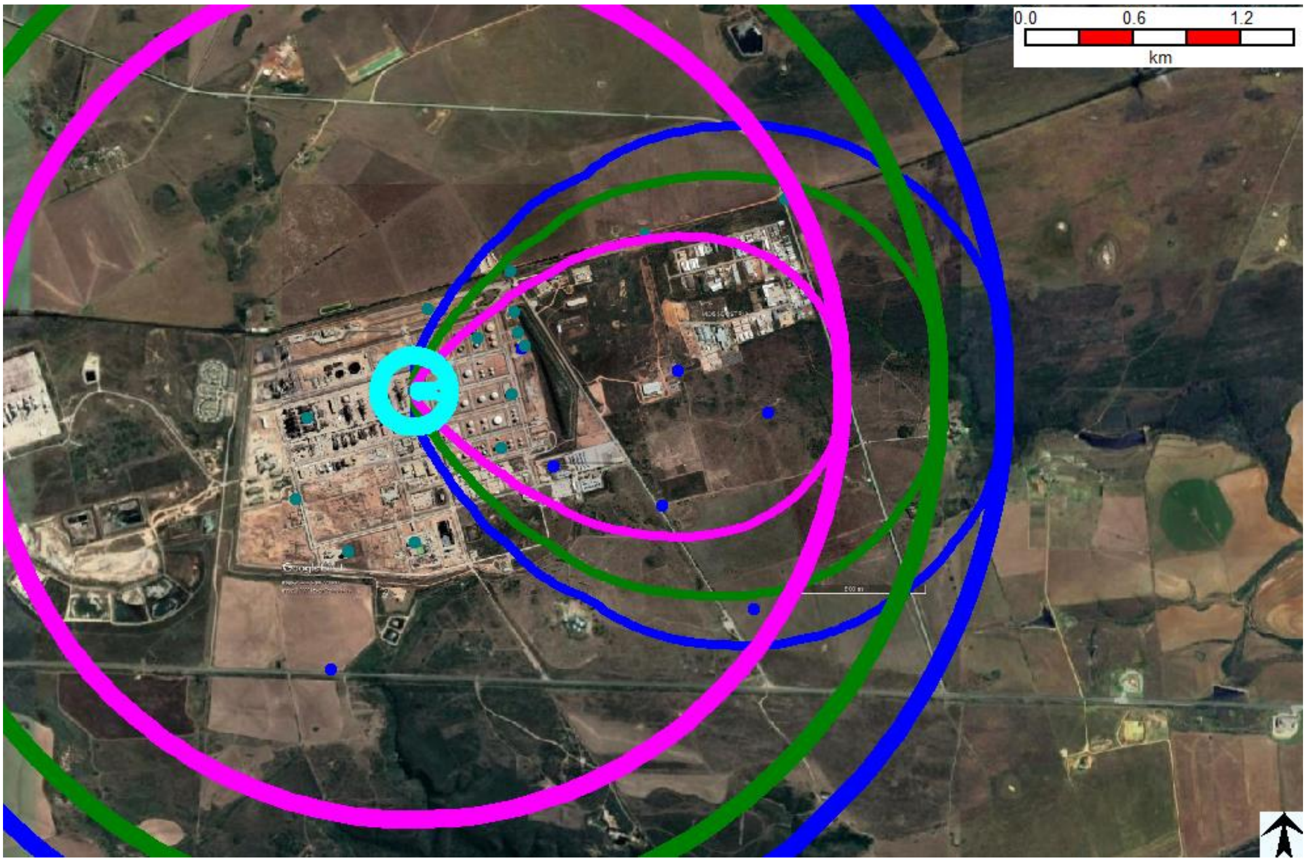


The following is the **WORST CASE SCENARIO** for the impact of PetroSA on the proposed development.

5.3.1.2 Map showing outdoor toxic lethality plumes for full bore rupture of the HF settler to reactor circulation pipe – pure HF phase

Bold circles show maximum extent in any wind direction. Faint plume is actual toxic cloud for night time weather conditions with a north-westerly wind.

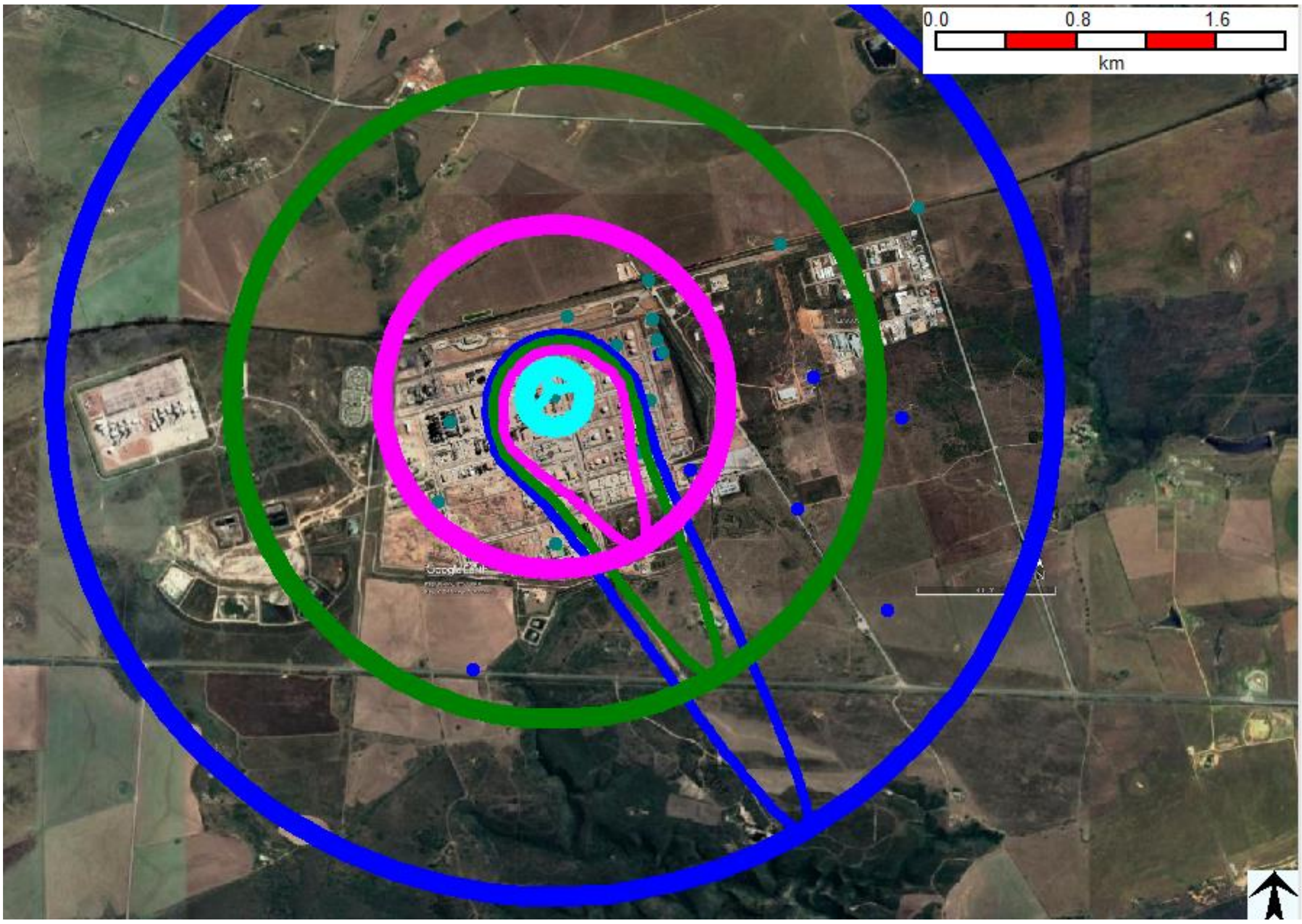
- Blue = 0.1% Lethality effect zone - 3300m radius within the plume
- Green = 1% Lethality effect zone - 2900m radius
- Pink = 10% lethal 2400 m radius
- Light blue – 100% lethal – 200m radius



5.3.1.3 Map showing outdoor toxic lethality plumes for catastrophic rupture of the HF settler to reactor system – mixed phase release

Bold circles show maximum extent in any wind direction. Faint plume is actual toxic cloud for night time weather conditions with a north-westerly wind.

- Blue = 0.1% lethality – 2850m downwind within the plume
- Green = 1% Lethality effect zone – 1800m radius
- Pink = 10% lethal 950 m radius
- Light blue – 100% lethal – 150m radius



5.4 IMPACT DISTANCES

The following levels of harm are considered significant if they enter the public domain:

- Toxics - 1% lethality
- Fire - 12.5 kW/m2 radiation levels
- Explosion - 14 kPa over pressure

The table below summarises the findings for PetroSA site according to these criteria. The table shows that there are toxic and flammable events that could have impacts in the development area, i.e. the development is not completely without risk if there were a fully operational PetroSA next door.

TABLE 5.4.1 – List of worst case events and impact distance for each major hazardous material

MATERIAL	STORAGE QUANTITY (largest single vessel)	WORST-CASE INCIDENT*	DISTANCE OF SIGNIFICANT LETHAL EFFECTS (m)	OFFSITE IMPACTS	MAJOR AFFECT ON DEVELOPMENT AREA
Compressed natural gas	Pipeline	Pipeline rupture – delayed isolation - explosion	145	No	No
Liquefied natural gas	10 000 m3	Rupture of bulk tank - explosion	800	Yes	Yes Western quarter
Biogas	< 1 Ton	Rupture of biogas system - explosion	100	No	No
Liquefied gases (Propylene)	2 000m3	Rupture of sphere - explosion	300	Yes	No
		BLEVE of a sphere	1000	Yes	Yes Western half
		Road/rail tanker loading hose rupture – 20 minutes to isolate	190	Yes	No
Petrol & Low flash point hydrocarbons	8 500m5	Rupture of tank - explosion	225	No	No
Hydrogen fluoride	20 Tons	Rupture of fresh acid holding tank – toxic gas cloud	1600	Yes	Yes
	15 Tons	Large puncture of the reactor settler system – toxic gas cloud	2900	Yes	Yes
TOTAL					**Yes Western Section of the Development area**

*Note that the events listed above are not the only events that could cause offsite effects, merely the events with the farthest offsite effects.

6. FREQUENCY ANALYSIS

Generic failure data, as well as data available from the site or similar sites is used to determine the likelihood of hazardous events.

Standard international world class failure data from reputable references (i.e. the Purple Book) can be adjusted according to the assessor's evaluation of the 'systemic organizational factors' in operation on site is (i.e., the level of maintenance and housekeeping, and how effective the actual implementation of any process safety management system etc.).

The PetroSA site was evaluated as having had very good policies procedures and practices in place in the past. However, it is not good for a chemical plant to be out of operation and recommissioning presents extraordinary risks. As a result, generic world class failure data for PetroSA was negatively adjusted to almost the maximum, i.e. a maximum penalty of a factor of 10 is allowed by SANS 1461 and PetroSA was adjusted by a factor of 8. A table with the frequency of each event can be found in the process data table in Section 4.

7. RISK CALCULATION

7.1 SAFETY RISK LEVELS

Two types of risk were evaluated in this risk assessment. They are outlined below, and more details are presented in Appendix 7.

Individual risk: The chance that a particular individual at a particular location will be harmed. It is usually described in numerical terms such as “number of fatalities per person per year”. The units are typically of one chance in a million of death per person per year and are shown as exponents i.e., 1 * 10^{-6} d/p/y. Criteria for individual risk are described in section 4.9.

Societal risk: Societal risks do not focus on the risk to a single individual but consider the risk of numerous persons being killed for a given event. Societal risk considers each incident modelled and the corresponding numbers of persons affected, to provide an idea of the scale of an accident. Societal risks are considered to ensure that high likelihood events do not result in (relatively) large amounts of fatalities. Criteria for societal risk are described in section 4.9.

Figure 7.1.1 – Offsite Individual Risk Isopleths for the key Scenarios at the PetroSA Installation
(Purple= 1E-5 d/p/y, Red=1E-6, Yellow=3E-7)
Note: 1E-4 = 1 * 10^{-4} or 0.0001

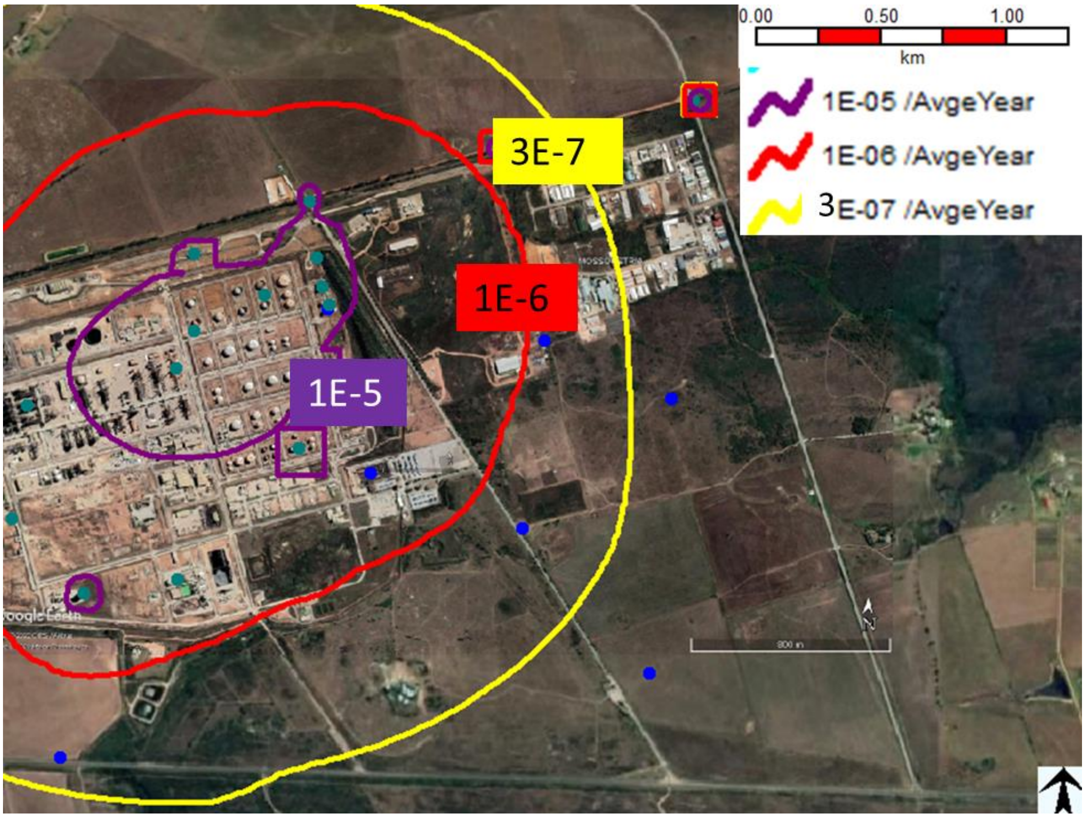
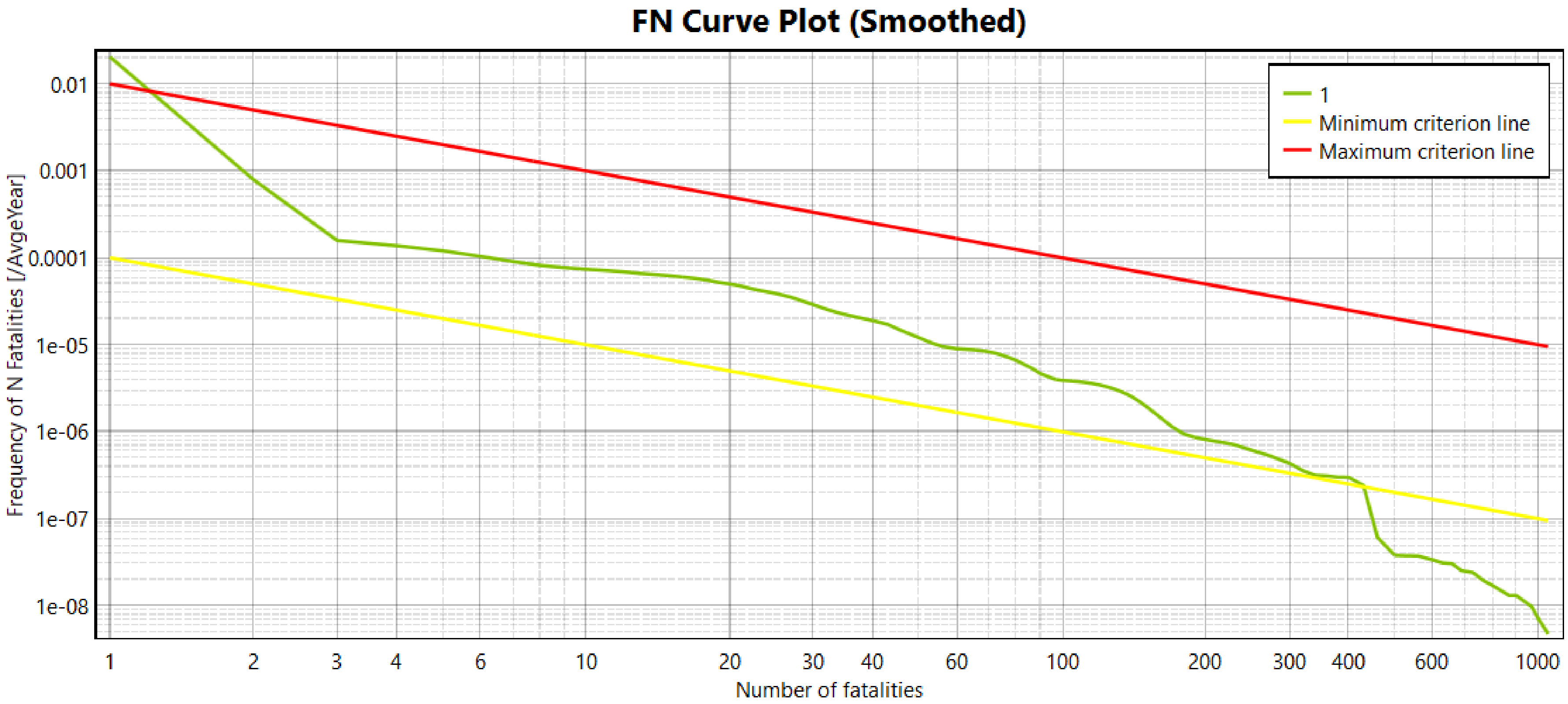


Figure 7.1.1 shows that the offsite risks are not intolerably high.
Since the red risk contour extends beyond the site boundary, the risks posed by PetroSA to the western section of Mossdustria (largely unoccupied) can be considered tolerable provided PetroSA have done everything reasonably practicable to reduce the risks (i.e. ALARP Range).
Over the eastern section of Mossdustria and the proposed motorsport / raceway area the risks are broadly acceptable.

Figure 7.1.2 – Societal Risk F-N Curve for the Area including a fully occupied Development (5 000 persons at the raceway)



The green line for the PetroSA risk should not be significantly above the red risk criteria line and ideally below the yellow line – societal risks are tolerably low, provided ALARP.

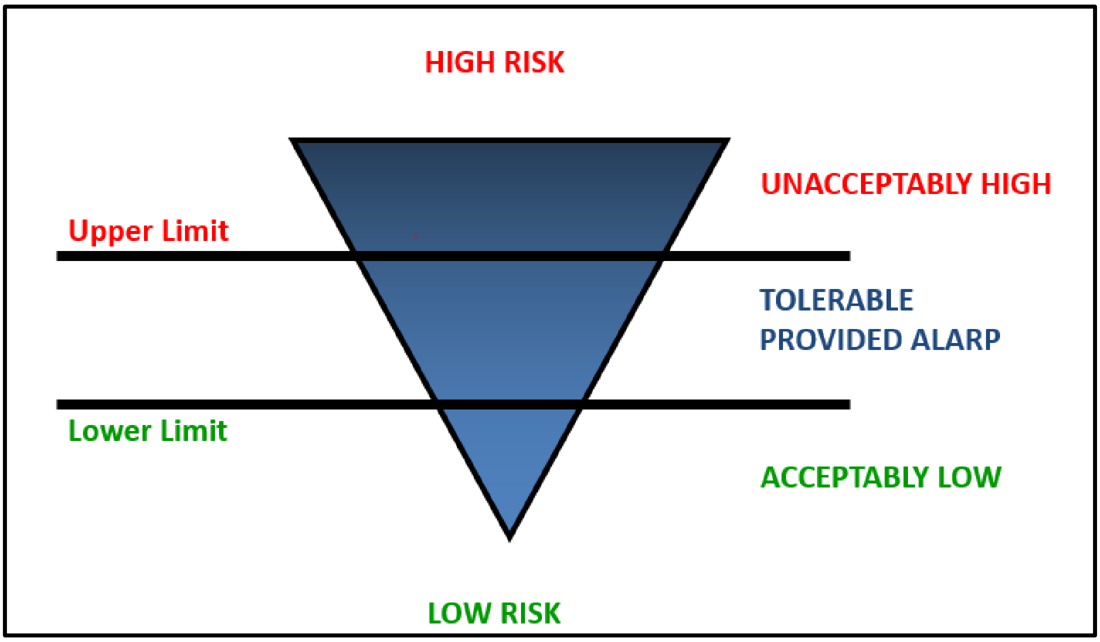
If there were 10 000 persons at the raceway, the curve would remain almost exactly the same except that it would have a small extension in the bottom right hand corner. The maximum number of fatalities would rise to 1950 with a likelihood of less than one in a billion, i.e. of similar likelihood to a meteorite falling onto the area.

8. RISK JUDGEMENT

8.1 INDIVIDUAL RISK

Individual risk can fall into one of three broad categories:

- Intolerably high
- Tolerable provided ALARP
- Broadly acceptable



With respect to acceptability of risk there are no agreed (or legislated) numerical criteria applicable in South Africa. The United Kingdom's Health and Safety Executive's criteria is widely used. These criteria are well developed, conservative and yet not stringent to the point of inhibiting industrial development. See Appendix 8.1 for a discussion on the acceptability of risk and the UK criteria.

Table 8.1.1 Summary of UK HSE individual risk criteria

RISK CLASSIFICATION	EMPLOYEES WITHIN SITE (chances in a million (cpm) of being fatally affected in any one year)	PUBLIC PERSONS (chances in a million (cpm) of being fatally affected in any one year)
Intolerably high	More than 1000	More than 100
Tolerable Provided ALARP	Between 1000 and 10	Between 100 and 1
Broadly acceptable	10 or less	1 or less

Risk levels vary as one moves away from or toward each hazardous installation. Cumulative risk levels for some key locations are presented in the table below. For each location, the material/equipment contributing most to the risk in each location is listed in the last column.

Table 8.1.2 – Individual risk levels at various locations

LOCATION	INDIVIDUAL RISK LEVEL (per million)	ASSESSMENT PER UK HSE CRITERIA	AREAS CONTRIBUTING TO THE RESIDUAL RISK
PetroSA Main Gate	0.56	Acceptably Low	▪ 86a&87a. HF circulation pipe from settler to reactor rupture ▪ 85. HF Holding tank small puncture ▪ 87 HF reactor settler system large puncture ▪ 86. HF reactor settler system rupture ▪ 7.Proylene sphere rupture ▪ 83. HF holding tank rupture ▪ 1. Propane sphere rupture
Mossdustria Central	0.78	Acceptably Low	▪ 86a&87a. HF circulation pipe from settler to reactor rupture ▪ 85. HF holding tank small puncture ▪ 7.Proylene sphere rupture ▪ 1. Propane sphere rupture ▪ 86. HF reactor settler system rupture ▪ 87 HF reactor settler system large puncture ▪ 19. Butylene sphere rupture ▪ 13. Butane sphere rupture ▪ 83. HF holding tank rupture ▪ 91. LNG tank rupture ▪ 84. HF holding tank large puncture
Pits area of the Proposed Development	0.21	Acceptably Low	▪ 86a&87a. HF circulation pipe from settler to reactor rupture ▪ 85. HF Holding tank small puncture ▪ 86. HF reactor settler system rupture ▪ 87 HF reactor settler system large puncture ▪ 83. HF holding tank rupture

The above table and the risk contours shown in Section 7.1 show that from an existing industry (PetroSA) point of view, unmitigated location specific individual risk levels outside the PetroSA site over almost all of the development area can be considered broadly acceptable, i.e. less than $1 * 10^{-6}$ d/p/y. Note that the risks an existing industry posed to the public already in the area may be acceptable, but that does not necessarily mean that additional members of the public can be brought into the area as this will increase the absolute number of persons exposed and may make societal risks unacceptable, see section 8.2 below.

8.2 SOCIETAL RISK

Figure 7.1.2 indicates that, apart from onsite immediately next to hazardous items of equipment, societal risks with up to 5000 persons at the raceway are tolerably low provided everything reasonably practicable has been done to reduce the risks (i.e.. ALARP).

The maximum number of fatalities for a worst-case scenario could be up to 1300 persons. The likelihood of this is less than once in 100 million years. These worst case events are due to catastrophic failure of the LPG gas spheres, dispersion of the vapour, delayed ignition with flash fire and vapour cloud explosion over populated areas. These events are extremely unlikely. More likely catastrophic failure events relate the HF system, but here the maximum number of fatalities is limited to less than 400 and the risk is still in the tolerable range as the likelihood is less than once 1 million years.

If the number of persons at the race track were as high a 10 000, the societal risks in the development area would remain tolerably low, although the maximum number of fatalities would rise to closer to 2 000.

Although not present in the UK HSE land use planning system, there is another criterion that is sometimes used in risk assessment called the Hong Kong criterion, named after the region that implemented it. This criterion states that from the results of a risk assessment it is unacceptable if there is a major hazard event with the potential to fatally affect significantly more than 1000 persons. With this criterion in mind it may be advisable to limit the size of large race events to 5000 persons, as with 10 000 persons the risks significantly exceeds the Hong Kong criterion.

8.3 RISK UNCERTAINTIES

The calculation of risk is affected both by the consequence modelling and the frequency estimates.

The consequence modelling is well known, and international software was used. Consequence modelling for the flammables therefore does not contribute greatly to the uncertainty and sensitivity of the offsite risks results. The model is however very sensitive to changes in the hydrofluoric acid system, e.g. increased inventory, higher processing conditions, failure modes etc. The model has taken a conservative worst case approach to the modelling.

Frequency estimates also contribute to the uncertainty especially with scenarios that are not readily available in international databases. When calculating these, this assessment has generally erred on the side of caution.

The above should translate into a risk model that rather overestimates the risks in the development area than underestimates them.

Obviously on-site risks were not the focus of this assessment and the risks on the PetroSA site will be significantly higher than are shown on these plots.

Overall, the uncertainties will not change the fundamental conclusions of this assessment that for the proposed development there are possible accidents that can impact in the area. However. due to a low likelihood of occurrence, the risks at the site are broadly acceptable for the proposed type of development provided the areas with the large numbers of public persons are on the eastern side of the site and public access to the western section is restricted. Refer to section 10 below for a detailed discussion.

9. RISK TREATMENT

Technical and organizational recommendations for the hazardous installation do not form part of this assessment.

10. LAND USE PLANNING

In terms of the Major Hazard Installation Regulations (MHI) there is a twofold responsibility placed on the local authorities when dealing with an installation that poses major hazards to the public outside the site. Initially they should ensure that the existing hazardous facility presents sufficiently low risks to existing neighbouring facilities and communities. Thereafter, they need to ensure that new developments within the area potentially affected by the MHI are of such a nature that persons are not unnecessarily exposed to high risks. For example, they should act to prevent of erection of hospitals close to Major Hazard Installations. There are no specific South African criteria that can be used to guide this process and to ensure suitable separation between developments.

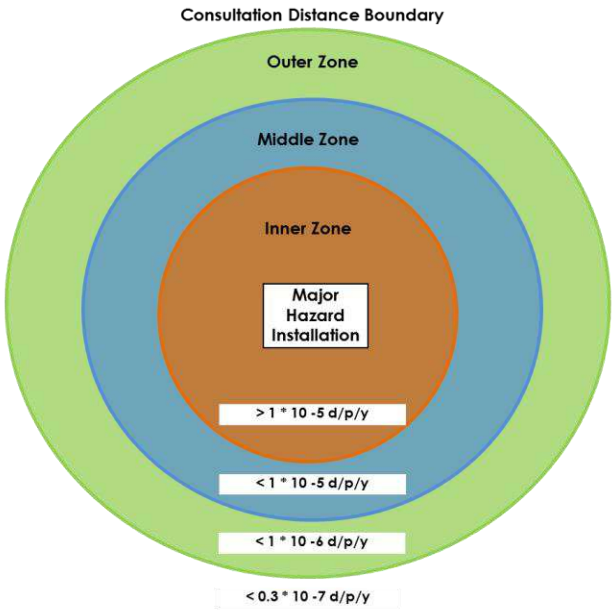
Therefore, in addition to any building restrictions in place with regards to pipeline servitudes, e.g. typically at least 3 – 6 m on either side of a fuel pipeline is a no building zone, the system used in the United Kingdom is generally adopted in the South Africa for dealing with MHI land use planning constraints.

The United Kingdom's Health and Safety Executive (HSE) have been, for a number of years, at the forefront of trying to establish a methodology to assist with land use planning close to hazardous Installation / Establishments. In 1989 they published "Risk Criteria for Land Use Planning in the Vicinity of Major Industrial Hazards." In 2001 the HSE published "Reducing Risks, Protecting People" which contained their philosophy with regards to evaluating risks and the process it utilised in decision making. The HSE has recently published "Planning Advice for Developments near Hazardous Installations" (PADHI Ref 27). In this document the HSE investigates the fundamental review of land use planning. PADHI utilises two inputs into a decision matrix to generate a response:

- which risk restriction zone the development is located in – there are 3 zones that make up the hazardous risk restriction zone around an MHI, and
- the "sensitivity Level" of the proposed development near the MHI which is derived from the HSE "Development Types" categorisation.

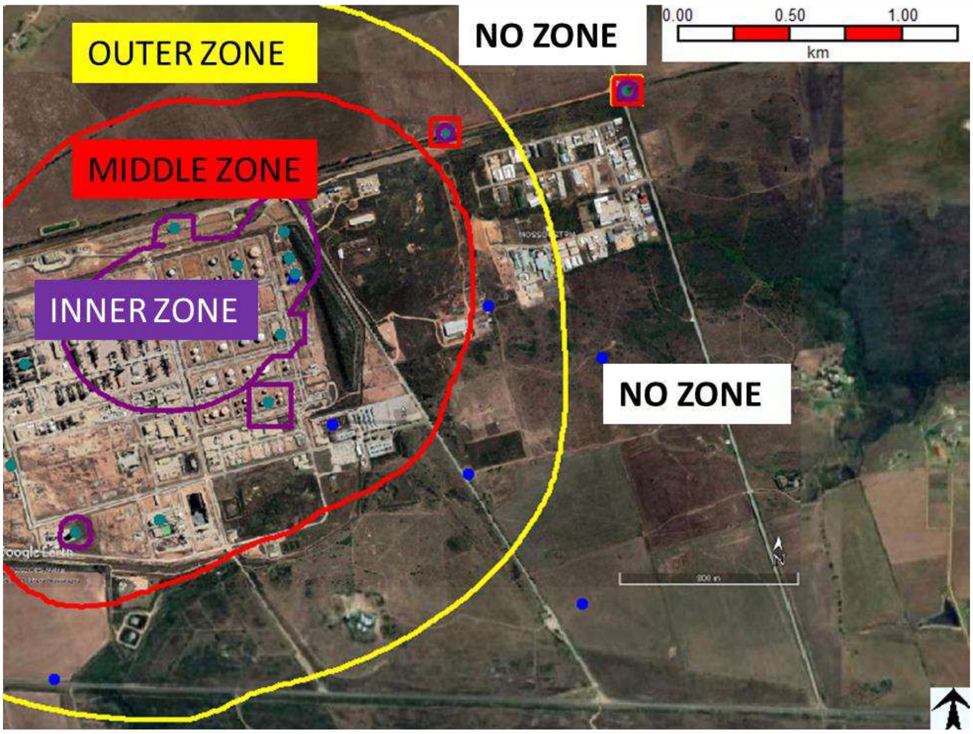
The HSE in the UK sets a consultation distance around major hazard sites and pipelines after assessing the risks and likely effects of major accidents at the Installation or pipeline. The Consultation Distance is comprised of three zones, these are designated as the Inner Zone (higher risk), the Middle Zone and the Outer Zone (lower risk). The following figure shows the logic behind this thought process for Major Hazard Installations in Figure 10.1.

Figure 10.1 Illustration of the HSE's Risk Based Zoning for Major Hazard Installations



In addition to the above risk-based zones, there are also consequence-based zones. In applying these consequence-based zones, cognisance should be taken of the low likelihood of extremely rare events.
The plot below shows the three risk-based land-use planning zones for the PertoSA Mossdustria area.

FIGURE 10.2 – Land-use Planning Risk Contours for Mossdustria Area
purple = 1 * 10 $^{-5}$ d/p/y – inner zone, red =1 * 10 $^{-6}$ – middle zone, yellow = <3 * 10 $^{-7}$ outer zone



Having set the zone around the industry/pipeline it is now necessary to analyse the type of development being proposed near the industry. This is done by determining the sensitivity level of developments. Each and every type of development, e.g. a housing estate, a school, a railway tec, can be considered to have a certain level of sensitivity to major hazards. To simplify this process, the UK HSE have developed a series of four sensitivity level categories. The sensitivity levels are based on a clear rationale in order to allow progressively more severe restrictions to be imposed as the sensitivity of the potentially affected population increases. As can be seen from Table 10.3 below, populations in level 4 developments are more sensitive than level 1 developments and therefore level 4 developments are usually sited further from the source of risk.

Table 10.3 Brief outline of sensitivity level categories

Sensitivity Level	Description
Level 1	Based on normal working population.
Level 2	Based on the general public – at home and involved in normal activities.
Level 3	Based on vulnerable members of the public (children, those with mobility difficulties or those unable to recognise physical danger
Level 4	Large examples of Level 3 and outdoor examples of Level 2

Below is an example of the detailed tables of the types of developments in one of these Sensitivity Levels (based on PADHI HSE's land use planning methodology May 2011). The reader is referred to the latest UK HSE PADHI documentation for the latest tables. Using these tables, it is possible to define into what sensitivity level any proposed development may fall.

Table 2 Development type: Developments for use by the general public (continued)

DT2.4 – Indoor use by public	**Exclusions**		
		DT2.4 x1 Development with less than 250 m² total floor space – **Level 1**	Minimal increase in numbers at risk
		DT2.4 x2 Development with more than 5000 m² total floor space – **Level 3**	Substantial increase in numbers at risk
DT2.5 – Outdoor use by public	**Food & drink:** Food festivals, picnic areas **Retail:** Outdoor markets, car boot sales **Community & adult education:** Open-air theatres and exhibitions **Assembly & leisure:** Coach/bus/railway stations, park & ride interchange, ferry terminals. Sports stadia, sports fields/ pitches, funfairs, theme parks, viewing stands. Marinas, playing fields, children's play areas, BMX/go-kart tracks. Country parks, nature reserves, picnic sites, marquees	Principally an outdoor development for use by the general public, ie developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time – **Level 2**	Developments where members of the public will be present (but not resident) either indoors or outdoors. Emergency action may be difficult to co-ordinate
	Exclusions		
	Outdoor markets, car boot sales, funfairs. Picnic area, park & 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
	Exclusions (continued)		
DT2.5 – Outdoor use by public	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 and emergency action may be difficult to co-ordinate

From the above table extracted from the UK PADHI reference (and the other tables in the reference), the aspects of the proposed development fall into the following sensitivity levels:

- A solar PV facility is the least sensitive type of development (i.e. a Level 1) as it has an extremely low occupancy and any persons present would be able bodied working staff.
- Industrial developments are split into two groups,
    - the least sensitive (Level 1) being small industries with no three storey buildings and no more than 100 persons per building,
    - facilities with either more than 3 storeys or more than 100 persons per building (Level 2),
- A large outdoor public facility such as the raceway with more than 1000 person present on occasions would be considered a very vulnerable facility with Sensitivity Level 4.

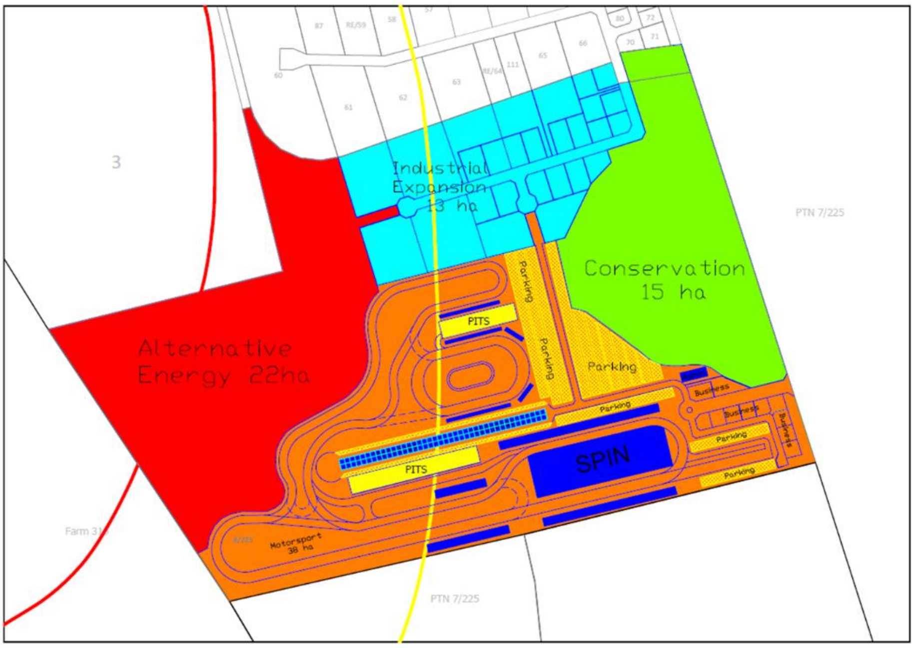
Having determined which risk zone the proposed development(s) falls into and also the Sensitivity Level of these developments, the following matrix in Figure 10.4 can be utilised to decide whether one should advise for or against each specific development. Beyond the outer risk zone there are no specified restrictions on developments.

Figure 10.4 - Decision matrix

Level of Sensitivity	Development in Inner Zone	Development in Middle Zone	Development in Outer Zone
Level 1	Do not Advise Against (DAA)	Do not Advise Against (DAA)	Do not Advise Against (DAA)
Level 2	Advise Against (AA)	Do not Advise Against (DAA)	Do not Advise Against (DAA)
Level 3	Advise Against (AA)	Advise Against (AA)	Do not Advise Against (DAA)
Level 4	Advise Against (AA)	Advise Against (AA)	Advise Against (AA)

Figure 10.5 below shows the proposed layout of the development in relation to the inner and outer zone lines. From this it is clear that most of the western section of the development site will be reserved for non-public alternative energy facilities. The densely populated public areas will be on the eastern side of the site.

Figure 10.5 – proposed layout of development
(solid dark blue areas are large public gathering areas, e.g. pavilions)



Using the above tables and risk zone plots for the area, it is clear that:

- there need be no restrictions on a solar PV development anywhere within the proposed development area.

- as there is no inner risk zone extending into the development area, there need be no restriction on industrial developments of any size.

- a large outdoor public facility such as the raceway (with well over 1000 persons) would not be advised within any of the risk zones. The development must be located beyond the risk zones. For the currently proposed development layout:
    - the eastern section is outside the outer zone in an area where there are no development restrictions,
    - the western section is inside the outer zone where large numbers of outdoor public persons should not gather. This western section should be a restricted area with no public access. Pavilions and public viewing areas must be on the eastern side, outside the outer risk zone. The race tracks themselves can extend in to the outer zone as it is unlikely that there would be more than 100 race drivers in this area at any one time,
    - if the pits are buildings where many back-up staff can go indoors in the event of an emergency, then they can be allowed to extend marginally into the outer zone, but if they are totally outdoor areas then they should be outside the outer zone,
    - In view of the Hong Kong risk criterion, it would be advisable to consider limiting the number of persons at large raceway events to 5 000 instead of 10 000.

Note that the above are merely suggestions and any decisions regarding land-use planning are entirely the responsibility of the local authorities in consultation with the developer and interested and affected parties.

11. EMERGENCY RESPONSE PLANNING

11.1 ON SITE EMERGENCIES

These can be emergencies arising on the PetroSA site that could have impacts in the development area.

All the facilities within the proposed development, and particularly the raceway, should have an Emergency Response Planning that is linked to the PetroSA site plan, e.g. PetroSA must have contact numbers for persons at the raceway in order to alert staff of possible hazardous events arising at PetroSA.

The raceway should consider how they would coordinate the shelter in place and/or the evacuation of large numbers of person out of the area in the event of an emergency developing at PetroSA, e.g. one of the worst case events, a BLEVE of one of the LPG spheres, would not be a sudden unnoticed event and would typically require other major initiating events. Provided warning actions by PetroSA are taken early, this would afford time to coordinate emergency evacuations.

11.2 EMERGENCY DRILL

All facilities in the development area should ensure that they practice their emergency procedures.

The Emergency Response Plan, particularly for the raceway, should be practiced regularly, e.g. small, localized drills quarterly and one large evacuation type dill annually. For the latter, even if one does not actually evacuate the public, practice setting up the systems on a very busy race weekend so that all role players know what they would do in the event of an actual emergency. The full evacuation can be physically practiced on a less busy day.

If possible, the raceway should take part in any large offsite emergency drills organized by PetroSA.

12. CONCLUSIONS AND RECOMMENDATIONS

12.1 CONCLUSIONS

Consequence Analysis

- The analysis found that the following are the materials present on the PetroSA site in sufficiently large quantities to possibly have offsite impacts should a major accident occur.

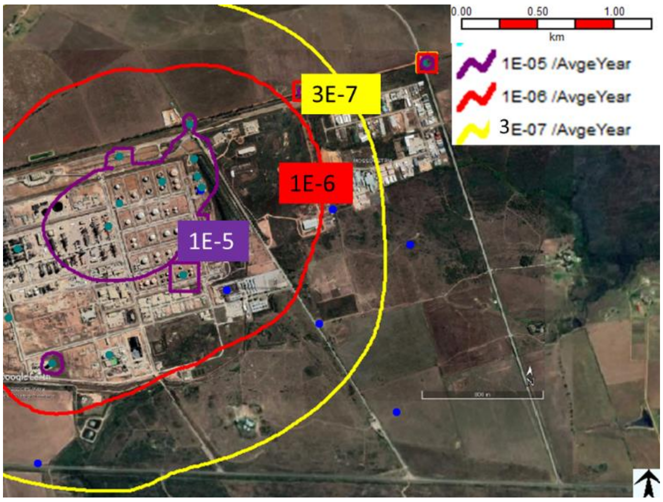
Bulk Hazardous Material	SANS10228 [Ref 2] Classification	Largest Vessel (t)
Methane (compressed natural gas, liquefied natural gas and biogas)	2.1 - Flammable gas	4 700
Liquefied gases (propane, propylene, butane, butylene, LPG)	2.1 - Flammable gas	1 200
Hydrogen fluoride	8 – Corrosive Liquid 6.1 Toxic liquid	20
Petrol	3.1 - Flammable liquid	6 000
Low flash point hydrocarbons (Condensate / naphtha / distillate etc)	3.1 - Flammable liquid	8 000
Diesel	3.1 - Flammable liquid	12 500

- Based on the consequence analysis, using SAFETI 8.61 software, the following are some of the possible offsite impacts:

MATERIAL	WORST-CASE INCIDENT*	DISTANCE OF SIGNIFICANT LETHAL EFFECTS (m)	MAJOR AFFECT ON DEVELOPMENT AREA
Compressed natural gas	Pipeline rupture – delayed isolation – vapour cloud explosion (VCE)	145	No
Liquefied natural gas	Rupture of bulk tank – delayed vapour cloud explosion	800	Yes Western quarter
Biogas	Rupture of biogas system – vapour cloud explosion	100	No
Liquefied gases (Propylene)	Rupture of sphere – vapour cloud explosion	300	No
"	Boiling Liquid Expanding Vapour Explosion (BLEVE) of a sphere	1000	Yes Western half
"	Road/rail tanker loading hose rupture – 20 minutes isolation VCE	190	No
Petrol & Low flash point hydrocarbons	Rupture of tank – vapour cloud explosion	225	No
Hydrogen fluoride	Rupture of fresh acid holding tank – toxic gas cloud	1600	Yes Entire area
"	Large puncture of the reactor settler system – toxic gas cloud	2900	Yes Entire area

Risks

- Combining the above consequence modelling with the estimated likelihood of the events the following is a plot of the Individual Risk Isopleths for the area. These contours show the chance, in any one year, of a typical person outdoors in the area being fatally affected by any of the major accidents that could happen at PetroSA, i.e. the red contour is the one in a million chance per year of being fatally affected and is similar to ones chance of being struck by lightning.



(Purple= 1E-5 d/p/y, Red=1E-6, Yellow=3E-7)
Note: 1E-4 = 1 * 10^{-4} or 0.0001

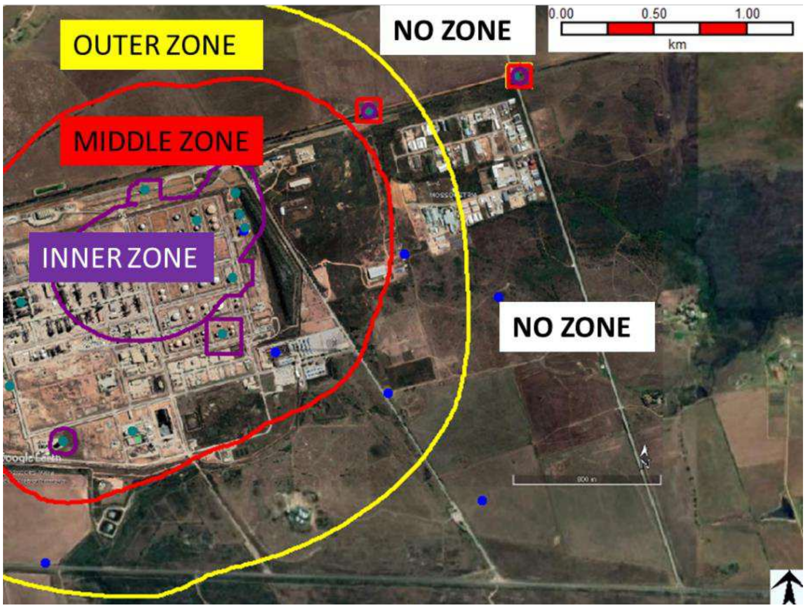
- The above risk contours show that, from an existing industrial facility perspective, the unmitigated location specific individual risk levels posed by PetroSA over most of the area where the development is intended to be, can be considered broadly acceptable, i.e. less than one in million chance of death per person per year.

- Societal risks, i.e. the absolute number of person possibly affected by the range of accidental events, are tolerably low, provided PetroSA have done everything reasonably practicable to reduce the risks. The maximum number of fatalities for a worst-case scenario with PetroSA fully functional and the proposed development fully populated (i.e. 5000 person at the raceway), could be up to 1300 persons. The likelihood of this is less than once in 100 million years.

Land Use Planning

- There are no specific South African criteria that can be used to ensure suitable separation between developments. The United Kingdom's Health and Safety Executive (HSE) have guidelines that are usually applied in South Africa. These guidelines are also referred to in the MHI Risk Assessment Standard SANS 1461.

- The HSE in the UK sets a consultation distance around major hazard sites and pipelines after assessing the risks and likely effects of major accidents at the Installation or pipeline. The Consultation Distance is comprised of risk base restriction zones called the Inner Zone (higher risk), the Middle Zone and the Outer Zone (lower risk). One can analyse the type of development being proposed near the industry and determine the sensitivity level of development. The UK HSE have published tables of typical developments and their suggested sensitivity level.
- The figure below shows the estimated risk restriction zones in the vicinity of PetroSA.



- Based on the above risk zones and land-use planning concepts:
  - A Solar PV facility is not a highly populated facility and would be the least vulnerable type of development. There would be no human impact risk based restrictions on this develop, i.e. it could be located within any zone.
  - Small industrial facilities such as those currently in Mossdustria and the proposed expansion, i.e. less than 3 storeys high and with less than 100 persons per building, would only be restricted in the inner risk zone which does not even extend beyond the PetroSA site. There will therefore be no restrictions on industrial developments of any size in the middle and outer zones.
  - A large outdoor public facility such as the Motorsport Raceway would likely be considered a very vulnerable facility, i.e. of the most sensitive level. Such a development would not be advised within any of the risk zones, i.e. the development must be located beyond the risk restricted zones.
  - Based on the proposed layout of raceway, it is clear that the western section falls within the Outer Restricted Land-use zone. This section should be designed to ensure no public access and there are to be no public pavilions etc. planned in this area. The public areas will be on the eastern side of the raceway site, largely where there is no restricted zone.
  - If the pits area have buildings within which pit staff can take shelter then they can extend marginally into the outer zone. If they are purely outdoors then they too should not be in the outer zone.
  - The race tracks themselves can extend into the western outer zone as it is unlikely that there would be more than 100 race drivers in the areas during an event.
  - Given societal risk impacts associated with the worst case events, it is advisable if the raceway events be restricted to 5 000 persons, i.e. not 10 000 persons.

Sensitivity

- The results of this assessment are sensitive to the process parameters and the modelling methods around the PetroSA hydrogen fluoride alkylation unit.

Emergency Plan

- Each facility within the development area is advised to have an Emergency Response Plan in place and to link the plan to the PetroSA plan. The plans should be practiced regularly (see section 11 for details).

12.2 RECOMMENDATIONS

The following recommendations have been made:

1. Based on the proposed layout of development (i.e. public persons in the eastern section and western sections being a restricted non-public area) and its location relative to the Land-Use Planning restricted risk zones around PetroSA (i.e. western section within the outer zone and eastern section not within any zone), there is no risk-based justification to advise against the development.

2. As the area where development is to be located is not entirely without risks from PetroSA (i.e. possible impacts from major accidents at the LNG tank, LPG spheres or the HF alkylation unit), facilities in the development should have an Emergency Response Plan and related facilities in place. The plan should link to the PetroSA site and its Emergency Response Plan. The plan should be practiced regularly.

3. Should the Petro SA HF alkylation facility be re-commissioned at some stage in the future, it is advised that the loading of fresh HF into the holding tank as well as the initial start-up of the reactor-settler unit be co-ordinated with motorsport/raceway such that the recommissioning does NOT take place at the same time as any racing events with large numbers (i.e. more than 100) of persons present at the raceway.

13. PROOF OF COMPETENCY

Refer to Appendix 1.

14. REFERENCES

1. “Occupational Health and Safety Act and Regulations 85 / 1993”, Sept 2003, Lex Patria, Butterworths, South Africa.
2. SABS, 2012,”SANS 10228 – The Identification and Classification of Dangerous Goods for Transport”, Standards South Africa, Pretoria.
3. API, September 1982, “Guide for Pressure-Relieving and Depressurising Systems”, API Recommended Practice 521, 2nd Ed, API, Washington, USA.
4. DNV, January 1995,”PHAST Professional User Manual – version 5.0”, DNV Technica, London UK.
5. ICI, July 1985, “Process Safety Guide No 10 – Risk Analysis Methodology – Part II – Procedures for Estimating the Consequences of Releases of Hazardous Substances”, Imperial Chemical Industries PLC, Standards Section, Cheshire, UK.
6. ICI, July 1985, “Process Safety Guide No 10 – Risk Analysis Methodology – Part I –Principals and General Practice”, Imperial Chemical Industries PLC, Standards Section, Cheshire, UK.

7. HSE, 2015, “The Control of Major Accident Hazards Regulations 2015 – Guidance on Regulations”, HMSO, London.
8. Lees, F.P, 1996, “Loss Prevention in the Process Industries”, 2nd Ed, Butterworth Heineman, Great Britain.
9. IchemE, 1999, “The Accident Database – version 4.1”, CD-ROM, Rugby, UK.
10. British Compressed Gases Association, “A Method for Estimating the Offsite Risks from Bulk Storage of Liquefied Oxygen”, BCGA 1999.
11. SABS, 2008,”SANS 10234 – Globally Harmonize System of classification and labelling of chemicals (GHS)”, SABS, Pretoria.
12. SABS, 2008,”Supplement to SANS 10234 – List of classification and labelling of chemicals in accordance with the Globally Harmonize System (GHS)”, SABS, Pretoria.
13. BEVI – Besluit Externe Veiligheid Inrichtingen Modules A,B and C (Dutch safety legislation)
14. Red, Yellow, Green and Purple Books, Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organisation for Applied Scientific Research)
15. Riswadkar,R and Mukhopadhyay,N, 1998, “RMP Hazard Assessment for Compliance with EPA’s Risk Management Program Regulations: OxyChem’s Experience”, Process Safety Progress, Vol 17 , No 4, pg 272 – 277.
16. DNV, April 2002, “Process Safety Management and Risk Assessment”, LP&PS MSc Course Notes, Sheffield University UK.
17. McBride, M, March 2003, “Assessing Chemical Warehouse Fire Risks”, LP&PS MSc Course Notes, Sheffield University UK.
18. N/A.
19. Smith, T.A. and Warwick, R.G., 1983, “A survey of defects in Pressure Vessels in the UK for the Period 1962 – 1978 and its Relevance to the Nuclear Primary Circuits”, International Journal of Pressure Vessels and Piping 1983, Vol 11, pg 127-166.
20. ICI, 1980, “Reliability data”, Imperial Chemical Industries, Mond Division, Technical Dept, Rep no MD 19128.
21. Du Pont, 1979, “Some published and estimated failure rates for use in fault tree analysis”, E.I. du Pont de Nemours, Applied Technology division, Wilmington, USA.
22. Du Preez, M,”SIL Review Preparation”, Experse Memorandum, June 2004, SS-UG-F-0104.
23. Pitblado, R and Turney, R, 1996, “Risk Assessment in the Process Industries”, 2nd Ed, IChemE, Warwickshire.
24. SANS 1016: part 4: “Basis of structural design and actions for buildings and industrial structures Part 4 seismic actions and general requirements for building”, SABS, Pretoria, 2011
25. SANS10313: “Protection against lightning – physical damage to structure and life hazard”, SABS, Pretoria, 2012.
26. SANS 1461:”Major Hazard Installation – Risk Assessments”, SABS, Pretoria, 2018.
27. UK HSE, “Planning Advice for Developments Near Hazardous Installation”, May 2011.

APPENDICES

APPENDIX 1
1.4 RISK ASSESSMENT PROCESS

APPENDIX 2
2.2. METEOROLOGY

APPENDIX 3
3.1 HAZARDOUS MATERIAL PROPERTIES
PHYSICAL AND FLAMMABLE PROPERTIES
HEALTH HAZARDS
TOXICITY

APPENDIX 4
LIST OF INCIDENTS CONSIDERED with process data
TYPICAL CAUSES OF EVENTS

APPENDIX 5
CONSEQUENCE ANALYSIS

APPENDIX 6
LIKELIHOOD ANALYSIS

APPENDIX 7
RISK ESTIMATION

APPENDIX 8
RISK JUDGEMENT

APPENDIX 1.4 RISK ASSESSMENT PROCESS AND COMPETENCY

Although this is not an MHI Risk Assessment, this study has been carried out largely in accordance with SANS 1461:2018 – Major hazard installations – Risk Assessments and ISHECON Work Procedures WP301 – MHI RA Assignment Administration and WP302 – MHI RA Methodology.

This study has been carried out by an appointed risk assessor, in accordance with ISHECON Work Procedure 102-Training and appointment of personnel.

I*SHE*CON uses a software package for quantitative risk assessment, SAFETI, under license from DNV in the UK (www.dnv.com). This study has been done on Version 8.61.

Although this is not an MHI Risk Assessment, ISHECONcc, and the risk assessor completing this assessment, are accredited to complete risk assessments, according to SANS 1461, of hazardous installations similar to PetroSA, see certificate.

MHI 0008

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:-

ISHECON CC
Co. Reg. No.: 1999/029022/23
MODDERFONTEIN

Accreditation Number: **MHI0008**

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 and National Standards

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: 13 June 2021
Certificate Expires: 12 June 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.

iSHEcon
CHEMICAL PROCESS SAFETY ENGINEERS

sanas Inspection Body

MHI 0008

ANNEXURE A

SCOPE OF ACCREDITATION

Accreditation Number: MHI0008

TYPE A

Permanent Address: ISHECON CC H6 Pinelands Office Park Maxwell Drive Modderfontein Ekurhuleni Gauteng 1645 Tel: (011) 201-4783 Cell: 082 348 0070 Fax: 086 549-0878 E-mail: bothad@ishecon.co.za	**Postal Address:** P O Box 320 Modderfontein Ekurhuleni Gauteng 1645 Issue No.: 13 Date of Issue: 11 June 2021 Expiry Date: 12 June 2025

Nominated Representative: Mr CF Botha	**Quality Manager:** Mr CF Botha **Technical Manager:** Mr DJE Rademeyer	**Technical Signatories:** Mr DJE Rademeyer Ms DC Mitchell Mr CF Botha

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 SANS 31000 SANS 31010 SANS 1461:2018

Original Date of Accreditation: 13 June 2005

Page 1 of 1

ISSUED BY THE SOUTH AFRICAN NATIONAL ACCREDITATION SYSTEM

Accreditation Manager

APPENDIX 2.2. TOPOGRAPHY AND METEOROLOGY

TOPOGRAPHY

The risk assessment software emission distribution package (SAFETI 8.61), does not take into account topography such as hills and valleys, nor local thermal conditions (upward currents due to heat generated by industries). However the surrounding land is classified according to its "surface roughness" which influences dispersion modelling.

The surface roughness parameter describes the roughness of the surface over which a vapour cloud is dispersing, and is a measure of the fluctuating velocity as a fraction of the mean velocity 10 m above ground.

Type of Surface	Roughness Length (m)
Open water, at least 5 km	0.0002
Mud flats, snow; no vegetation, no obstacles	0.005
Open flat terrain; grass, few isolated objects	0.03
Low crops; occasional large obstacles, x/h > 20	0.10
High crops; scattered large obstacles, 15 < x/h < 20	0.25
Parkland, bushes; numerous obstacles, x/h < 15	0.5
Regular large obstacle coverage (suburb, forest)	1
City centre with high- and low-rise buildings	3

iSHEcon
CHEMICAL PROCESS SAFETY ENGINEERS

sanas Inspection Body
MHI 0008

METEOROLOGY

WIND AND WEATHER INFORMATION

JOHANNESBURG WIND AND WEATHER DATA (2013)
(Temperatures from Weather SA and wind from SA Weather Bureau)

	SUMMARY OF WIND AND WEATHER DATA FOR MOSSEL BAY																			
																		Ambient	**Surface**	
																		Temp	**Temp**	**Humidity**
		N	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**	**S**	**SSW**	**SW**	**WSW**	**W**	**WNW**	**NW**	**NNW**	**Deg C**	**Deg C**	**%**
Day	**F1.4**																			
	B3	0.30	0.40	0.59	1.58	2.67	1.58	1.19	0.79	1.38	1.58	2.37	1.98	2.57	1.98	1.19	0.59	23	23	72
	D4.5	0.14	0.07	0.07	0.87	2.68	1.74	0.72	0.29	0.65	2.32	2.90	2.17	3.04	1.30	0.58	0.29	23	23	72
	D7.2	0.00	0.00	0.00	0.00	0.30	0.59	0.05	0.20	0.10	1.04	1.88	1.14	1.43	0.30	0.20	0.20	23	23	72
	TOTAL	0.44	0.47	0.67	2.45	5.65	3.91	1.96	1.28	2.14	4.94	7.15	5.29	7.05	3.58	1.96	1.08			
																	50.00			
Night	**F1.4**	2.24	2.63	2.83	2.63	3.03	2.04	1.84	2.44	2.34	2.04	3.03	3.03	3.03	4.02	3.03	2.53	14	23	83
	B3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14	23	83
	D4.5	0.05	0.03	0.03	0.32	0.98	0.64	0.27	0.11	0.24	0.85	1.06	0.80	1.11	0.48	0.21	0.11	14	23	83
	D7.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14	23	83
	TOTAL	2.29	2.66	2.86	2.95	4.01	2.68	2.11	2.54	2.58	2.89	4.09	3.83	4.14	4.50	3.24	2.64			
																	50.00			

There are three Pasquill stability conditions are normally applicable namely:

- Unstable: Sunny hot day (A, B, C).
- Neutral: Overcast day or night (D).
- Stable: Clear, cold night (E, F).

APPENDIX 3.1 PROPERTIES OF HAZARDOUS MATERIALS

EXPLOSION, FLAMMABILITY AND REACTIVITY HAZARDS

Compound	Cn	BP at 1 atm (deg C)	SG at 20deg C kg/m3	Flash point (deg C)	Explosive limits in air (vol %)	Auto-ignition Temperature (deg C)
Condensate	Cn 3 – 10	-88 - 125	0.7	< 0 - 12	1 - 13	
Reformate	Cn 4 - 9,	104-116	0.85	4	1 - 13	
Methane	Cn 1	-161	0.55	Vap	5 – 15	540
Petrol	Cn 6 - 10	43	0.52 @ 38 C	-34	1.4 – 7.6	220
Diesel	Cn 12 - 20	193	0.0003	55	1.3 - 6	229
LPG (butane 60% propane 40%)		-40	1.5	-100	Y - 9	400

HEALTH HAZARDS ASSOCIATED WITH CHEMICALS

With respect to the detrimental health effects of chemicals on the public, it is really only the inhalation effects that are relevant. Skin contact and ingestion effects are only applicable to workers who are in immediate contact with the chemicals. This assumption has been confirmed for any of the sites, as there are no large storage vessels that could fail leading to either a spray or pool of immediately harmful liquid flowing off site.

Compound	Hazardous Breakdown / Combustion Products	Inhalation Acute	Inhalation Chronic	Ingestion Contact Acute	Ingestion Contact Chronic
Condensate, reformate, diesel and slops	Carbon mon / di - oxide	Irritating to the respiratory tract	None	Irritating to the eyes	Mild skin discomfort
Methane / LPG	Carbon mon / di – oxide	Drowsiness and asphyxiation	None	Frostbite (if contact with refrigerated liquid)	None
Hydrofluoric acid	Hydrogen fluoride	Irritation of respiratory tract, onset of symptoms may be delayed for several hours. Burns, pulmonary oedema, death. Depletion of calcium in body leading to death (delayed)	Irritation of respiratory tract (delayed). Depletion of calcium. Bone and joint changes.	Severe and fatal burns. Profound and possible fatal depletion of calcium even with dilute solutions.	Irritation, burns. Depletion of calcium. Bone and joint changes.

Compound	Odour Threshold (ppm)	Time Weighted Average OEL ** (ppm)	Short Term Exposure Level *** (ppm)	Immediately Dangerous to Life and Health **** (ppm)	LC 50 (30 mins)	ERPG 1 Value ***** (ppm)	ERPG 2 Value (ppm)	ERPG 3 Value (ppm)	PROBIT k1 ~~	PROBIT k2	PROBIT n
Petrol	0.25	300	500 (30 min)			500	500	1500	-	-	-
Diesel	0.7	NA	NA			100	500	500	-	-	-
Methane	200	None		Asphyxiant		3 000	5 000	20 000	-	-	-
Hydrogen fluoride	0.03 mg/m3		3	20		5	20	50	-8.701	1.5	1

** - TWA Threshold Limit Value – the time weighted average for a worker exposed 8 hours per day for a 40 hour week

*** - STEL short term exposure limit for a worker exposed to not more than the TWA but with a maximum of 4 excursions to this limit per day for a maximum duration of 15 minute each with at least 60 minutes between exposures

**** - IDLH (Immediately Dangerous to Life and Health) a value that is believed on the basis of research to be immediately harmful to human health, i.e. irrecoverable damage to health within 30 minutes exposure

***** - The ERPG (Emergency Response Planning Guidelines) values are established by the American Hygiene Association and are based on a 60 minute exposure.
The three categories have the following implications in terms of effects on people:
ERPG1 - below this concentration only minor irritation should be experienced by almost all persons
ERPG2 - below this value no permanent harm
ERPG3 - below this value permanent harm possible but fatalities are unlikely
ERPG values (and TEEL values) can be found through the AIHA website or the US Department of Energy website or the US EPA website.

d - where ERPG values or TEEL values are not available they have been derived using a DOW chemical guideline where ERPG2 = STEL or 3 * TWA, ERPG3 = LC50/30 or 5 * ERPG2, ERPG1 = Odour threshold or ERPG2/10, if there are different values the lower more conservative value has been used

~~ - Probit is an estimation of chance of death from exposure to a concentration of toxic material (c in ppm) for a period of time (t in mins)
PROBIT = k1 + k2 * ln (c^n t). Probit equation is based on actual or experimental data and can be found in literature references, e.g. the TNO Purple Book.

APPENDIX 4 FULL LIST OF INCIDENTS CONSIDERED AND PROCESS DATA

Name	Mass inventory	Temperature	Pressure (gauge)
	kg	degC	bar
1. Propane Sphere Catastrophic rupture	986000	22.99998	8.0430926
2. Propane Sphere Large liquid puncture	986000	22.99999	8.043094937
3. Propane Sphere Large vapour puncture	986000	22.99999	8.043094937
4. Propane Sphere Small liquid puncture	986000	22.99999	8.043094937
6. Propane Sphere Internal explosion	60	360	0.001
7. Propylene Sphere Catastrophic rupture	1026000	22.99997	10.03294526
8. Propylene Sphere Large liquid puncture	1026000	22.99998	10.03294805
9. Propylene Sphere Large vapour puncture	1026000	22.99998	10.03294805
10. Propylene Sphere Small liquid puncture	1026000	22.99998	10.03294805
11. Propylene Sphere PSV fails open	1026000	22.99998	10.03294805
12. Propylene Sphere Internal explosion	60	360	0.001
13. Butane Sphere Catastrophic rupture	1146000	22.99998	1.275643921
14. Butane Sphere Large liquid puncture	1146000	22.99999	1.275644643
15. Butane Sphere Large vapour puncture	1146000	22.99999	1.275644643
16. Butane Sphere Small liquid puncture	1146000	22.99999	1.275644643
17. Butane Sphere PSV fails open	1146000	22.99999	1.275644643
18. Butane Sphere Internal explosion	60	360	0.001
19. Butylene Sphere Catastrophic rupture	1240000	22.99997	1.777726767
20. Butylene Sphere Large liquid puncture	1240000	22.99998	1.777727626
21. Butylene Sphere Large vapour puncture	1240000	22.99998	1.777727626
22. Butylene Sphere Small liquid puncture	1240000	22.99998	1.777727626
23. Butylene Sphere PSV fails open	1240000	22.99998	1.777727626
24. Butylene Sphere Internal explosion	60	360	0.001
25. LPG Bullets Catastrophic rupture	182325	22.99998	5.769957594
26. LPG Bullets Large liquid puncture	182325	22.99999	5.769959388
27. LPG Bullets Large vapour puncture	182325	22.99999	5.769959388
28. LPG Bullets Small liquid puncture	182325	22.99999	5.769959388
29. LPG Bullets PSV fails open	182325	22.99999	5.769959388
30. LPG Bullets Internal explosion	9	360	0.001
31. LPG Transfer pipe Line rupture Isolated 5 minutes (ROSOV) 300	10230	22.99999	5.769959388
32. LPG Transfer pipe Line rupture Isolated supervisor 20 mins 1200	40920	22.99999	5.769959388
33. LPG Transfer pipe Line leak Isolated 5 minutes (ROSOV) 300	450	22.99999	5.769959388
34. LPG Transfer pipe Line leak Isolated supervisor 20 mins 1200	1800	22.99999	5.769959388
35. LPG Loading hose Line rupture Isolated 2 minutes (OEI) 120	1620	22.99999	5.769959388
36. LPG Loading hose Line rupture Isolated supervisor 20 mins 1200	16200	22.99999	5.769959388
37. LPG Loading hose Line leak Isolated 2 minutes (OEI) 120	48	22.99999	5.769959388

38. LPG Loading hose Line leak Isolated supervisor 20 mins 1200	480	22.99999	5.769959388
39. LPG Road or rail tanker Catastrophic rupture	30000	22.99999	5.769959388
40. LPG Road or rail tanker Large liquid puncture	30000	22.99999	5.769959388
41. LPG Road or rail tanker Large vapour puncture	30000	22.99999	5.769959388
42. LPG Road or rail tanker Small liquid puncture	30000	22.99999	5.769959388
43. LPG Road or rail tanker PSV fails open	30000	22.99999	5.769959388
91. LNG System	4207896.919	-160.3292755	0.1
96. Offshore gas pipeline	39674.56574	23	35
98. Gas pipeline to/from LNG	39674.56574	23	35
100. Anaerobic digester	611.9603682	50	0.01
83. HF Holding tank Catastrophic rupture	20000	22.99998	3.5
84. HF Holding tank Large puncture	20000	22.99999	3.5
85. HF Holding tank Small puncture	20000	22.99999	3.5
86. HF Alky-reactor Catastrophic rupture	85000	39.99999	13
87. HF Alky-reactor Large puncture	85000	39.99999	13
88. HF Alky-reactor Small puncture	85000	39.99999	13
86. HF Circulation pipe Rupture Isolated 5 minutes (ROSOV) 300	15000	39.99999	13
88. HF Circulation pipe Leak Isolated 5 minutes (ROSOV) 300	15000	39.99999	13
87. HF Circulation pipe Rupture Isolated 20 minutes 1200	15000	39.99999	13
89. HF Circulation pipe Leak Isolated 20 minutes 1200	15000	39.99999	13
90. Synthol rupture	250100.38	240	30

45. Low flash Tanks north Catastrophic rupture	6400000	23	
46. Low flash Tanks north Large puncture	6400000	23	
47. Low flash Tanks north Small puncture	6400000	23	
48. Low flash Tanks north Overfill	98630.13699	23	
50. Low flash Tank east Catastrophic rupture	6400000	23	
51. Low flash Tank east Large puncture	6400000	23	
52. Low flash Tank east Small puncture	6400000	23	
53. Low flash Tank east Overfill	98630.13699	23	
55. Low flash Tanks south Catastrophic rupture	6400000	23	
56. Low flash Tanks south Large puncture	6400000	23	
57. Low flash Tanks south Small puncture	6400000	23	
58. Low flash Tanks south Overfill	98630.13699	23	
60. Low flash Transfer pipe Line rupture Isolated 5 minutes (ROSOV) 300	50400	23	
61. Low flash Transfer pipe Line rupture Isolated supervisor 20 mins 1200	201600	23	
62. Low flash Transfer pipe Line leak Isolated 5 minutes (ROSOV) 300	1710	23	
63. Low flash Transfer pipe Line leak Isolated supervisor 20 mins 1200	6840	23	
64. Low flash Rail filling hose Rupture Isolated 2 minutes (OEI) 120	2592	23	
65. Low flash Rail filling hose Rupture Isolated supervisor 20 mins 1200	25920	23	
66. Low flash Rail filling hose Leak Isolated 2 minutes (OEI) 120	36	23	

67. Low flash Rail filling hose Leak Isolated supervisor 20 mins 1200	360	23	
68. Low flash Rail tanker Catastrophic rupture	40000	23	
69. Low flash Rail tanker Large puncture	40000	23	
70. Low flash Rail tanker Small puncture	40000	23	
71. Low flash Cross country pipeline (Moss west) Rupture Isolated 20 minutes 1200	237600	23	
72. Low flash Cross country pipeline (Moss west) Rupture	6400000	23	
73. Low flash Cross country pipeline (Moss west) Leak Isolated 20 minutes 1200	11160	23	
74. Low flash Cross country pipeline (Moss west) Leak	6400000	23	
75. Low flash Cross country pipeline (Moss cent) Rupture Isolated 20 minutes 1200	169200	23	
76. Low flash Cross country pipeline (Moss cent) Rupture	6400000	23	
77. Low flash Cross country pipeline (Moss cent) Leak Isolated 20 minutes 1200	11160	23	
78. Low flash Cross country pipeline (Moss cent) Leak	6400000	23	
79. Low flash Cross country pipeline (Moss east) Rupture Isolated 20 minutes 1200	139200	23	
80. Low flash Cross country pipeline (Moss east) Rupture	6400000	23	
81. Low flash Cross country pipeline (Moss east) Leak Isolated 20 minutes 1200	11160	23	
82. Low flash Cross country pipeline (Moss east) Leak	6400000	23	

TYPICAL CAUSES OF EVENTS

Primary cause events

Most hazards are due to loss of containment events and possible causes are the following:

Failure of equipment:

- Deterioration of the equipment integrity (physical impact damage, material of construction failure e.g. stress corrosion cracking) followed by thorough inspections throughout the life of the equipment.
- Deterioration of the plant integrity (material of construction failure) causing a rupture of equipment and piping. This may be as a result of a crack developed in the piping or equipment material due to fatigue from vibration, stress corrosion cracking or an inherent fabrication defect not detected during X-ray inspection. Such a rupture could then be initiated by, e.g., a pressure surge, or external damage from actions of people. Failure is normally in the form of small cracks. The best assurance against failure is correct design, specification, fabrication and construction procedure followed by thorough inspection, but this is no guarantee against the possibility for material of construction to fail.
- Uncontrolled pressure rise: in the pipes and vessels due to liquid blocked-in between two isolation valves, or liquid exposed to fire, or compressor discharge pressure being higher than expected, due to surging, etc. Lines can be protected by bursting discs. Alternatively run away reactions or the mixing of incompatible chemicals can also lead to reactions inside vessels/containers leading to over pressurization or the release of toxic gases
- Failures of the preventative equipment e.g. computer controls, control instruments and hardware trips.
- Failure of the protective / mitigative hardware barrier equipment e.g. deluge water,

Failure of systems:

- Failure of the preventative systems through human or management system errors (e.g. inadequate instruments).
- Failure of the protective / mitigative systems through human and procedural errors. E.g. creation of an open end through incorrect venting or opening of drain valves.

Secondary cause events

Possible causes for ignition (fire & explosions) of flammable or combustible materials are:

- Hot work
- Static spark discharges and lightning
- Electrical faults
- Smoking
- Failure of nitrogen blanketing systems.
- Ingress of foreign oxidising materials (e.g. air or strong acids) into the system containing flammable materials and then some form of ignition of the mixture. This is generally caused by inadequate purging during shut down and start-up operations. The source of ignition is often hot work tools during maintenance, warming up procedures, static or high process temperatures.

Possible causes for toxic exposure or gassing of people from released materials are:

- Not wearing personal protective equipment
- Lack of awareness
- Failure to evacuate

- Inadequate provision of gas escape facilities on site (only for toxic gases).

Minor and rare causes

Since the assessment mainly deals with the major hazards of explosion, fire and toxic releases, the following causes were excluded:

- Small general leaks, which may include valve spindle seal leaks, leaks due to normal wear, or improper maintenance.
- Natural events (earthquakes, storms, floods, etc.)
- External or internal sabotage as a result of personnel grievances.
- Aeroplane crashes into facility.

APPENDIX 5 CONSEQUENCE ANALYSIS

MAGNITUDE OF SOURCE TERM

In terms of the rate of release the following are generally applicable:

For vessels including road tankers or drums, the following scenarios are usually considered;
- complete rupture,
- a large hole the size of the largest appurtenance (typically 25 - 52 mm),
- a small hole the size of a typical flange leak or valve stem leak (typically 1 - 10 mm).

For pipes:
- complete severance (full bore),
- a small leak (the size of a typical flange leak, 10 mm).

These scenarios were used to evaluate the consequences using a modelling package called SAFETI (version 8.61). This package has built in fluid dynamics simulations and prior to simulating the consequences, accurately calculates the flows due to ruptures, leaks etc. based on pressures, temperatures, pipe diameters and material properties.

In terms of the duration of incidents where specific information is not available or calculable, the duration was estimated using the British Health and Safety Executive (HSE) standards [Ref. 5]:

5 seconds	for normal lifting and re-seating of relief valve
1 minute	for automatic detection and isolation e.g. in the event of a pipe rupture and rapid de-pressurisation leading to a plant trip
5 minutes	for remotely operable isolation e.g. operator responds to panel alarm and can isolate either on the panel or at strategically located external isolation valves.
20 minutes	operator is required to isolate manually directly at or very close to the source of the release e.g. required to don a BA set and move through vapour cloud to close a valve.

DISPERSION

Dispersion of gas clouds is governed by the prevalent weather conditions including:

- Wind speed and direction (essentially horizontal mixing)
- Stability of the atmosphere (essentially vertical mixing)

The latter is essentially the extent to which wind turbulence, which is responsible for the dispersion, is suppressed or assisted. On cold windless nights, cold air is trapped close to the surface of the earth and any gas release will not be easily dispersed. On the contrary, on a hot summer's day there is generally a lot of turbulence in the air due to heating of the earth's surface and the air in contact with it. This aids dispersion of gases. These conditions had been labelled with the letters A to F.

The principal results from dispersion calculations are the concentrations at ground level at various distances downwind from the release source. In addition concentration isopleths in the vertical and horizontal planes can also be obtained. There are many dispersion combinations, due to the different probabilities of weather stability's and wind speeds. The wind direction was considered only for the eight major wind directions and the percentage of time that the wind is blowing in a particular direction was used to determine the final risk levels.

Following dispersion of the vapour the flammable or toxic concentrations can be determined at certain key distances from the installation. The effects will also be determined at these key distances.

EVENTS INVOLVING FLAMMABLE MATERIALS

The release of a flammable material can result in many different effects depending on the particular circumstances of the release. A pressurized release (e.g. pipe leak) that is ignited immediately and close to the source will result in a jet (liquid) or torch (vapour) fire. If the liquid is not ignited or it is not pressurized at the point of release it will from a pool on the ground. Vapours will evaporate off the pool. Multiple factors may catalyse the speed at which vapours are released; such as the volatility of the material, increased surface temperature, increased wind strength and/or spill surface area. In the case of release of vapour or liquefied gases a cloud of vapour or vapour with entrained liquid droplets (mist) will be formed directly.

This cloud of flammable vapour (either from the pool or directly from the vapour release) can drift with the wind and disperse. If the cloud disperses to below its lower flammable limit then it cannot be ignited. However, while it is dispersing the area of the cloud where the vapour is below the upper flammable limit and above the lower flammable limit can be ignited. If the cloud is in an open uncongested, unconfined area a vapour cloud fire or so called "flash" fire will result. The fire will "flash" back from the point of ignition to the point of release. At the point of release there will now be either a jet fire or pool fire or both.

However, if the cloud of flammable gases has drifted into areas where it is confined within pipe work, plant structures, buildings, vessels, forests etc. the ignition may lead to a vapour cloud explosion. The strength of the explosion will depend on the properties of the material involved. However, another critical factor is the particular layout of the congested / confined areas in which the gas is located. Within one release event there may be areas where the gas is extremely confined and other areas where the gas is out in the open. Each of the pockets of ignited gas may have different effects: some may explode while others are essential flash fires. The direction in which the gas burns through the areas (i.e. the manner in which the flame front is broken up by obstacles) may also result in different flash fire zones or explosions with strength effects.

The consequences of each of the flammable hazardous events are radiation burns, blast and shock wave damage and possible damage due to missiles. In general, every flammable release will have radiation and explosive effects. However, depending on the type of release either the radiation or the over-pressure (explosion) effects will dominate the severity of the consequences. For example the explosive effects of a jet fire are negligible in comparison with the radiation effects and vice versa for a confined vapour cloud explosion. With condensed phase explosions (e.g. explosives or certain organic peroxides – NOTE, not present on this site) it is the over-pressure element as well as ground vibration that can have significant effects.

The major consequence of an explosion is the shock wave effect. The shockwave shatters glass, damages equipment and can cause fatalities; either directly through rupture of bodily organs, or indirectly through structures collapsing onto people. The consequences of fires are damage to equipment and radiation burns to people. In terms of burns there are two aspects that are important, namely the intensity of the radiation and the duration of exposure. Details of the overpressures and radiation levels that lead to specified degrees of harm are present below.

FLAMMABLE EFFECTS

The following overpressures are usually considered in a risk assessment.

TABLE 5.1 – Levels of Damage at Key Explosion Overpressures

Over-pressure (kPa)	**Injuries / Fatalities**	**Structural Damage**	**Other**
100	100 %	Typical blast wall design limit	
70	> 90 %	Almost complete demolition of plant 100% damage	
35	Eardrum Rupture	80 % damage	
14	**< 1%**	**40% damage**	**HSE development separation distance**
7	Injuries, no fatalities	5 % damage	
4		Minor structural damage	HSE safe housing consultation distance
0.7			Maximum missile distance
0.3	Loud noise	Large glass windows break	

An explosion generally produces missiles as well as over-pressure wave. With respect to missiles it is unlikely that they will travel kilometres to affect the public directly, and moreover the large area of possible strikes means that the probability of a public fatality is so low that it is generally not worth considering as a major hazard.

The consequences of fires are damage to equipment and radiation burns to people. In terms of burns there are two aspects that are important, namely the intensity of the radiation and the duration of exposure. In quantifying the magnitude of a fire the information is presented in the form of radiation intensities for simplified specific exposure times. It is assumed that 1 minute is insufficient time to escape from the source of the threat. In this regard the following radiation guidelines have been used.

TABLE 5.2 – Levels of Damage at Key Fire Radiation Levels

Radiation Intensity kW / m2	Exposure Limit (time)	Consequence
75	5 secs	100% lethal
37.5	1 min	100 % lethal, will damage process equipment and structures
26	1 min	50 % lethal, permissible structure exposure level
12.5	**1 min**	**< 1 % lethal**
4	1 min	No fatalities expected
1.6		Pain Threshold, typical flare design limit
1.2	Unlimited	Equivalent to midday sun

This means that any person in the 37.5 kW/m^2 radiation circle for a minute is likely to be fatally burned, while there is a 50% chance of those persons between the 12.5 and 37.5 kW/m^2 radiation circles being fatally burned within a minute. Outside of the 12.5 kW/m^2 radiation level there are less than 1% fatalities.

<u>TOXIC EFFECTS</u>

In addition to probit equations, it is often useful to have a single number or single concentration of toxic vapours that can be used as a first approximation to the extent of dangerous exposure. For example there is the concentration which is deemed to be Immediately Dangerous to Life and Health (IDLH) and it is the concentration that can cause significant harm to almost all persons within 30 minutes of exposure.

Another single number that is often used is the Emergency Response Planning Guidelines that were developed by a consortium of chemical companies under the auspices of the American Industrial Hygiene Association. These guidelines indicate the maximum exposure concentrations that can be endured for 60 mins (i.e. a reasonable evacuation period) with certain levels of effects.

ERPG 1 - only mild irritation will result
ERPG 2 - no permanent damage
ERPG 3 - no life threatening health effects (Possible permanent damage)

Often the ERPG3 and IDLH concentrations are often similar. Generally emergency services would consider evacuation of persons who could be exposed to ERPG 2, ERPG 3 or IDLH concentrations depending on their resources. Therefore, the local emergency services need to know the distance at which the gas concentration would drop below this concentration under both probable and well as worst-case release scenarios.

APPENDIX 6 LIKELIHOOD ANALYSIS

OPERATOR AND EQUIPMENT FAILURE DATA

1. Equipment Failure

Most of the failures leading to potential major hazards are associated with loss of containment as a result of vessel or pipe rupture, or due to leaks. For the purpose of this assessment ruptured vessels and pipes tank were considered as representing the worst-cases. Failure data was taken from the manual published by the Dutch Government Committee for the Prevention of Disasters viz. “Guidelines for Quantitative Risk Assessment” CPR 18E (1999) [Ref 22], known in the industry as the Purple Book. Examples of the frequency data used are presented below.

Note: 1E-8 = 1 * 10^{-8} or 0.00000001

EQUIPMENT	FAILURE	FREQUENCY Failures/year
Full containment atmospheric tank (i.e. semi-explosion and missile penetration proof double containment tank)	instantaneous release	1 E-8
Atmospheric tank with protective outer shell	- instantaneous release - small release to secondary container	5 E-7 1 E-4
Single walled atmospheric containment tank	- instantaneous rupture - 10 minute release of entire inventory - 10 mm hole	5 E-6 5 E-6 1 E-4
Pressure vessel	- instantaneous rupture - 10 minute release of entire inventory - 10 mm hole	5 E-7 5 E-7 1 E-5
Process vessels and reactors	- instantaneous rupture - 10 minute release of entire inventory - 10 mm hole	5 E-7 5 E-7 1 E-5
Pipes Ø < 75 mm	- Rupture - leak	1 E-6 /metre 5 E-6 /metre
Pipes 75 mm <Ø < 150 mm	- rupture - leak	3 E-7 /metre 2 E-6 /metre
Pipes Ø > 150 mm	- rupture - leak	1 E-7 /metre 5 E-7 /metre
Pumps (canned)	- catastrophic failure - leak	1 E-5 5 E-5
Pressure relief valve fails open		2 E-5
Storage of explosives	Mass detonation	1 E-5
Road tanker (atm)	- instantaneous rupture - large leak - hose rupture - hose leak - arm rupture	1 E-5 5 E-7 4 E-6 /hour 4 E-5 /hour 3 E-8 /hour

EQUIPMENT	**FAILURE**	**FREQUENCY Failures/year**
	- arm leak	3 E-7 /hour
Road tanker (pressure)	- instantaneous rupture - large leak - hose rupture - hose leak - arm rupture - arm leak	5 E-7 5 E-7 4 E-6 /hour 4 E-5 /hour 3 E-8 /hour 3 E-7 /hour

2. Human Failure

Source	Person	Task Level	Failure Rate Prob of Error
ICI	Operator	Simplest	$1*10^{-4}$
		Routine	$1*10^{-3}$
		Should take care, e.g. a checklist is needed	$1*10^{-2}$
		Non routine	$1*10^{-1}$
		Checking another operator	$1*10^{-1}$
	Supervisor	Checking an operator	$1*10^{-2}$
Du Pont	Operator	Simple	$1*10^{-3}$
		Checking another operator or shift change-over	$1*10^{-1}$

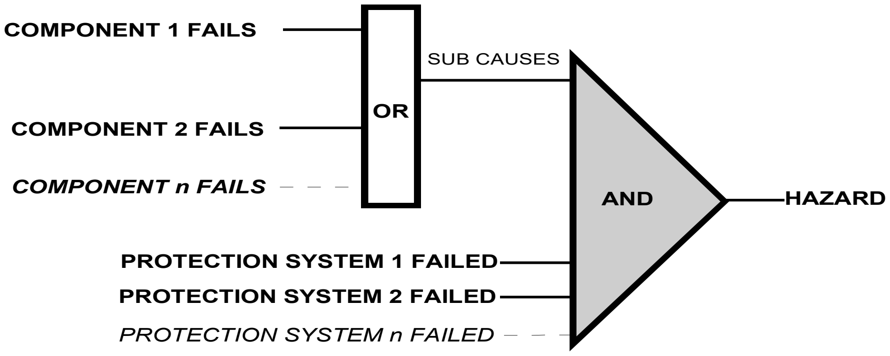
3. Organizational Measures and System Failures

The standard of maintenance, the implementation of operating and emergency procedures and the general safety management systems in place on site can have a significant effect on the failure rates used. Pitblado (Ref. 19 pg 115) states that one can adjust generic data based on an assessment of the particular plant effectiveness at maintenance, safety systems etc. The basic standard of safety should be 1, i.e. neutral if good maintenance, operating and emergency procedures in place. Many plants fall below this standard; hence failure data should actually be increased up to a maximum of one order of magnitude. For those that are of world class standard and have much more that the basic safety systems in place the failure data can be reduced by up to one half an order of magnitude.

Measures in the organisation to reduce the major risks have been evaluated, and suggestions for improvements made in section 9.1 of this report.

4. Simple Fault Trees

For most events in this study the simple failure rates above were not sufficient to estimate the final likelihood of a hazardous event. This is due to the layers of protection provided on the plant. Simple fault trees were compiled for most events. A fault tree is essentially a logic diagram, which represents the development of events from the root causes with failure data in terms of their frequency or probability of occurrence to the final 'top' event or hazard as illustrated below.



For these risk assessment very simple fault trees were compiled. For example the following were included:

- the generic equipment failure data (as listed above)
- the number of drums, tankers, lengths of pipeline etc,
- the amount of time that the equipment is On-site and in use (e.g. for road tankers)
- the ability of operator to respond or not or to cause failures (e.g. for stopping transfer if alarms provide warning),
- the likelihood of failure of any automated shut off valves, excess flow valves, ventilation, scrubbers or any ESD's etc the general perceived level of Safety Management on site (see systems failure above).

APPENDIX 7 RISK CALCULATION

INDIVIDUAL RISK

Individual risk: The chance that a particular individual at a particular location will be harmed. It is usually described in numerical terms such as "number of fatalities per person per year" or "one fatality per person per, e.g. 1000, 10 000, 100 000, $10^{6,}$ etc. years". The units are typically of one chance in a million of death per person per year, and are shown as exponents i.e. $1 * 10^{-6}$ d/p/y.

Assessment of individual risk does not take into account the total number of people at risk from a particular event, or the possibility that people may take action to escape the effects of a toxic gas or fire etc. The individual risks were determined based on the combination of frequency or likelihood of events and their severity, taking into account ignition probabilities and the distribution of the weather conditions in terms of stability, wind speed and direction.

The individual risks can be plotted on a map of the site. This has been done and is shown on Figure 7.1.1 for the all the activities on the installation. On the map all the areas where risks are lower than $1 * 10^{-7}$ d/p/y lie outside the $1 * 10^{-7}$ d/p/y risk contour (i.e. the green line), and the same for the other higher risk contours. The map easily allows one to see where certain risk levels e.g. $1 * 10^{-6}$ extend beyond the site boundary.

SOCIETAL RISK

Individual risk referred to above considers the risk to a typical individual but does not consider how many individuals could be affected. Communities have a strong aversion to large events, which lead to multiple fatalities. Therefore, the frequency of events that lead to multiple fatalities should be suitably low. The F-N curve attempts to represent this concept graphically and to set some standards. The graph shows the frequency of accidents on the 'y-axis', and the maximum number of fatalities that could result from this accident on the 'x-axis'

Societal risk includes the population in the vicinity, and estimates the chances of numbers of people being harmed by an incident. The likelihood of the primary event (an accident at a major hazard plant) is still a factor, but the consequences are assessed in terms of level of harm and numbers affected, to provide an idea of the scale of an accident in terms of total numbers killed or harmed. Estimates of the societal risks incorporate the population distribution during day and night, as well as the location of people indoors or outdoors. (See the table below for the population data used). The results are presented in the form of an F-N curve. This plots the number of persons potentially fatally affected by every one of the potential events on site, against the frequency with which these levels of fatalities can be expected to occur

POPULATION ESTIMATIONS

The area around the site was split into zones such as each of the neighbours, or the general surrounding industrial area, residential areas, open spaces etc. The population in each area was either estimated from a count of houses or based on known information such as employee records or the typical population density was used for that type of area, e.g. typical industrial areas have a density of between 40 -100 persons per hectare depending on the type of activity. For this information the guidelines in the Green Book 1992 [Ref 23] were used. The Green book also suggests guides on day versus night time occupation of certain areas, e.g. 100 % of a population would be in a residential area at night but during the day 70% leave to go to work. A probability that people would be indoors was assigned to each population area, based on the guidelines Green Book 1992. See Table 5.10.1 below.

Night / Day	Area	Population	Density (persons / m2)	Fraction indoors
Night time population	Liq Gas Tank Farm	4.8E-05	1	0.01
	North Gantry	1.7E-04	2	0.01
	Tanks farm	5.1E-06	2	0.01
	Lower tank farm area	1.1E-04	10	0.5
	Admin area	1.7E-05	2	0.99
	Mos gas main plant	6.0E-05	100	0.99
	Hostel	2.5E-03	200	0.99
	Mossdustria NE	1.9E-05	10	0.01
	Mossdustria MW	3.8E-06	2	0.01
	Mossdustria SW	0.0E+00	0	0.01
	Mossdustria SE	0.0E+00	0	0.01
Daytime population	Liq Gas Tank Farm	4.8E-05	1	0.01
	North Gantry	4.2E-04	5	0.01
	Tanks farm	2.6E-05	10	0.01
	Lower tank farm area	1.1E-04	10	0.5
	Admin area	8.6E-04	100	0.93
	Mos gas main plant	1.2E-04	200	0.93
	Hostel	1.3E-03	100	0.93
	Mossdustria NE	2.9E-04	150	0.5
	Mossdustria MW	5.7E-05	30	0.5
	Mossdustria SW	8.6E-06	2	0.01
	Mossdustria SE	3.3E-03	2000	0.01

Being indoors gives protection that is affected by the air exchange rate in building and the time it takes to clear a room of gas after an event. For normal buildings this study used an air exchange rate of 4 ACH (Air Changes per Hour) and a tail time of 1800 sec.

APPENDIX 8 RISK ASSESSMENT CRITERIA

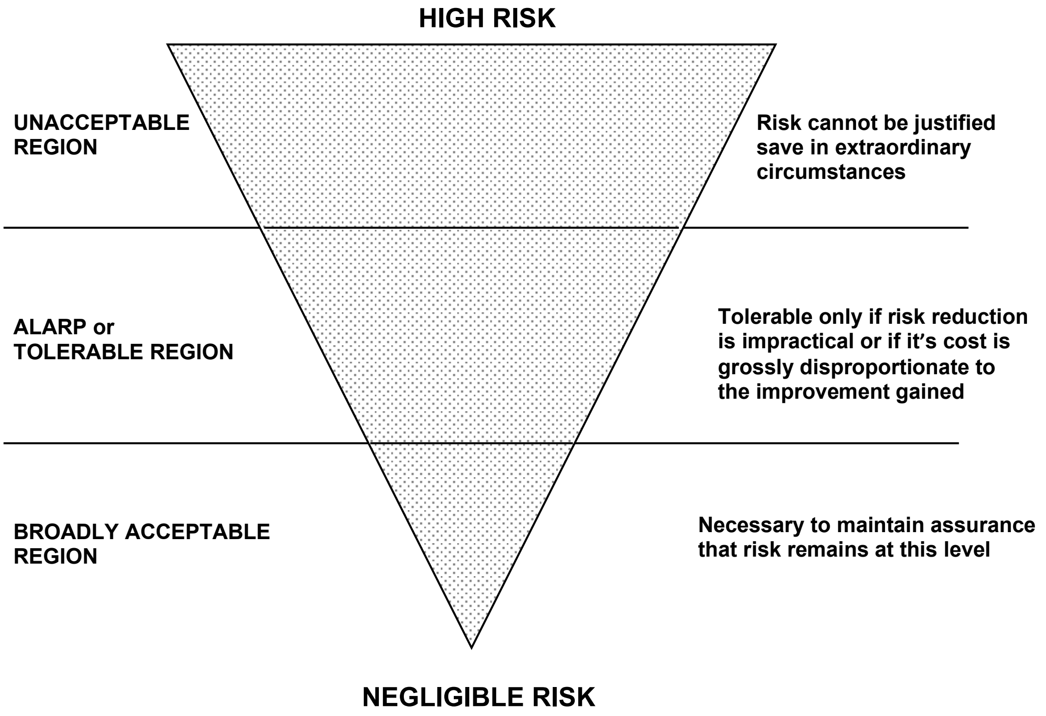
INDIVIDUAL RISK

Risks that major hazard installations pose to persons are usually represented quantitatively as the chance in any one year of a typical person being fatally affected by an accident on the site. The acceptability of chemical risks is related to the other risks to which persons in society are exposed. Risks that are accepted voluntarily by persons are often quite high while risks that are not voluntarily accepted, e.g. the risk of so called acts of God, are quite low. The table below shows some risks that individuals tolerate.

ACTIVITY / HAZARD	RISK *
Becoming a homicide victim (RSA)	410 chances in a million
Becoming a traffic fatality (RSA)	220 in a million
Becoming a traffic fatality (UK)	6 in a million
Becoming a victim of some other accident (e.g. drowning, electrocution UK)	2.5 in a million
Being struck by lightning (RSA)	1.5 in a million
Being struck by lightning (UK)	0.05 in a million
Being struck by a falling aircraft (world-wide)	0.01 in a million

- - approximate risk rounded-off data UK from “Reducing Risks, Protecting People” , Traffic RSA AA 1997, Crime CIAC SAPS 2004/5

Once an approximation of the risk has been made it is possible to judge that risk according to agreed criteria and establish if it is acceptable or unacceptable to persons who may be affected. In many cases there is no clear and easy distinction between what is acceptable and unacceptable. There is a zone between these two extremes where risks could be tolerated provided they are as low as reasonably practicable (ALARP). The installation whose risks fall into this category, need to prove that they have done everything reasonably practicable to reduce risk. The ALARP principle in illustrated below:



The dividing lines between the zones, e.g. unacceptable and tolerable, can be set at different levels depending on the situation e.g. who is affected, whether they also receive benefits in addition to the risks etc.

In residential areas, a public risk level of 10^{-6} chances of death per person per year (i.e. 10^{-6} d/p/y = one in a million chances of death in one year) is accepted in the United Kingdom as being a broadly acceptably risk to which people could be exposed [Ref. 8]. This risk is more than 10 times higher than the risk of being struck by lightning in the UK and is therefore considered virtually negligible. In the UK, public risk levels in excess of 10^{-4} d/p/y are considered to be unacceptable, and immediate attention should be given to reducing the risk. In the area between 10^{-4} and 10^{-6} risks are tolerable but not negligible and therefore some form of risk management program should be instituted with the aim of reducing risks within the constraints of what is practicable and reasonable. This range is referred to as the ALARP range, i.e. risks should be as low as reasonably practicable

In industrial areas the risk levels should be similarly low. However, it is possible that slightly higher risks could be tolerated than in residential areas provided everything reasonably practicable has been done to reduce the risks. This assumes that employees at neighbouring industrial sites are generally fit, healthy, able to be trained in emergency procedures etc. Within the broader manufacturing industry in the UK, the average employee serious injury rate is $2.3 * 10^{-5}$ d/p/y. The risks that a new installation poses to employees of adjacent industrial installations should not exceed the risk to which they would normally be exposed at work. The individual risk to employees of neighbouring installations should therefore be below $1*10^{-5}$ d/p/y. (Note ideally it should be below the $1*10^{-6}$ d/p/y as these persons are also members of the public).

SOCIETAL RISK

In the case of major hazard installations the more persons that are potentially exposed to the effects of accidents the greater will be the absolute number of persons that could be affected by any one event. In terms of fatalities there is no distinction between employees and the public, i.e. 100 deaths is serious whether it is employees or public persons. Major hazard installations that are located in remote uninhabited areas will pose lower societal risks that the same industries located near residential areas, despite the fact that both industries could pose identical individual risks.

In all communities there is an aversion to large accidents that affect many people at once. For example in South Africa we appear to 'tolerate' a road accident fatality rate of about 30 persons per day. It is only the very large accidents where typically 10 or more persons are affected that may jog our awareness and make us consider that the road traffic accident situation is 'intolerable'. The same would apply to major hazard installations. Therefore in addition to considering the risks to a typical individual near an installation, it is important to consider the possible impact on the absolute numbers of persons potentially exposed. This gives an indication of how many persons could possibly be affected in any one accident.

There has been a debate internationally about whether employees should also be included as part of the population. The Health and Safety Executive in the United Kingdom has adopted the principle that workers located on a major hazard installation subjected to Occupied Building Controls will be excluded from societal risk assessments. As there are no binding Occupied Building Regulation in RSA, employees on the site were included in the societal risk evaluation.

The UK HSE's have recommended societal risk guidelines [Ref 15]. The criteria are that there should be no chance that more than 50 persons could be fatally affected by accidents on the site more often than once in 5000 years. The criteria are presented in the form of an F-N curve. This shows the number of persons potentially fatally affected by each and every one of the potential events on site and the frequency with which these levels of fatalities can be expected to occur

MHI008

APPENDIX 11