REPORT:	**MAJOR HAZARD INSTALLATION RISK ASSESSMENT FOR PRE-CONTRUCTION NOTIFICATIONS** **ETHEKWINI MUNICIPALITY** SOUTHERN WORKS FACILITY
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REPORT ADMINISTRATIVE RECORD

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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:

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SUPPORTING DOCUMENTATION

The validity, results and conclusions of this assessment are based on the following information, drawings, reports and documentation of the plant and equipment:

DOCUMENTS	DRAWINGS	OTHER INFORMATION
FSR - SWWTW -SRTFU - ver 4	55616SH1	Email information from Sharleen Moodley
	55616SH2	
	55616SH3	
	54931/C/01/001/P	

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This document was proof read by Debbie Mitchell on 3 February 2015.

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EXECUTIVE SUMMARY

eThekwini Metro Water and Wastewater are responsible for the treatment of all municipal sewage in the greater eThekwini area. The Southern Waste Water Treatment Works (SWWTW) facilities process sewer effluent that is a combination of domestic and industrial in origin. It receives the majority of its raw sewage effluent through three large trunk sewers. SWWTW propose to begin treating the effluent instead of pumping it out to sea. A physical treatment process (through primary settling) will result in the organic load to sea being drastically reduced. The settled solids (referred to as primary (or raw) sludge) will then be removed and stabilised through a process of anaerobic digestion, before being dewatered. The biogas produced will be stored and likely utilised on site. SWWTW will refurbish and bring on-line a number of existing items of decommissioned processing equipment, as well as constructing new facilities. SWWTW requested an opinion on the classification the site as a Major Hazard Installation. The Classification study found that the site was indeed an MHI. This classification necessitates a full MHI Risk Assessment. This report summarizes the ISHECON MHI Risk Assessment review of 2014.

Although this assessment is based on the best available information and expertise, ISHECON cannot be held liable for any incident that may occur on this installation and associated equipment which directly or indirectly relate to the work in this report.

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.

The risk assessment therefore includes the following:

- Identifying the likely major hazards expected to be associated with the operation of the installation 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].
- Reviewing the suitability of the emergency plan and organisational measures in terms of the risks.
- Proposing measures to reduce or eliminate the risk where necessary.

2. Findings

[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.

This assessment has found that it is possible, under abnormal accident situations, for the biogas to be stored on site to have a significant impact on public persons outside the site. The most significant being:

– Biogas gas holder rupture and delayed explosion with significant effects up to 145m.

Hazards, which have the potential to harm members of the public beyond the site boundaries, are classified as major hazards and the facilities from where they originate as a Major Hazard Installation. Therefore, the SWWTW must be classified as a major hazard installation, due to the biogas facilities and the possible fatal impact of potential fire and explosion type events associated with them.

As a requirement of the EIA process, two possible design alternatives are being considered for this project. For *Alternative 1*, it was found that the risk of being fatally exposed to the major hazards associated with the new biogas facility would be about 75 * 10^{-6} fatalities per person per year near the existing gas holder, reducing to 0.002 * 10^{-6} at the NW site boundary. For *Alternative 2*, it was found that the risk of being fatally exposed to the major hazards associated with the new biogas facility would be about 210 * 10^{-6} fatalities per person per year near the existing gas holder, reducing to 210 * 10^{-6} at the NW site boundary.

In terms of the acceptability of risks to the public, the United Kingdom's Health and Safety Executive's criteria, which are well-developed, conservative and yet not stringent to the point of inhibiting industrial development, were used. Their criteria regard an individual risk of less than 1 * 10^{-6} fatalities per person per year as acceptable. A risk greater than 1 * 10^{-4} is regarded as unacceptably high. In between these two levels risks can be considered tolerable provided everything reasonably practicable has been done to reduce the risks (i.e. the As Low As Reasonably Practicable (ALARP) principle).

Thus for *Alternative 1*, risks to the public outside the SWWTW site are tolerable, provided ALARP. For *Alternative 2*, risks are **unacceptably high** at the site boundary.

Regarding risk to employees within a typical organisation, a risk level of 1 *10^{-3} fatalities per person per year (i.e. one in a thousand) is accepted in the United Kingdom as being the maximum tolerable. This risk is an order of magnitude higher that the risk of suffering a fatal or near fatal accident in normal life (i.e. the work situation is adding to an employee's general risk level), but this increase in risk is offset by the benefits of employment (i.e. remuneration). A risk of less than 1 * 10^{-5} is regarded as totally acceptable. In between these two levels risk is tolerable but the ALARP principle applies. Thus the risks of 75 * 10^{-6} per person per year for *Alternative 1* and 210 * 10^{-6} for *Alternative 2* posed to employees on the SWWTW site are both tolerable provided ALARP.

According to the United Kingdom's Health and Safety Executive's societal risk criteria, risks are intolerable if fatalities of 50 or more people can happen in a single event more than once in 5 000 years (2 * 10^{-4}) or 500 or more people more often than once in 50 000 per year (2 * 10^{-5}). This defines a range of limits above which societal risks are unacceptable and continued operation should not be allowed. There is also a lower limit, set two orders of magnitude lower, below which an installation would be regarded as totally acceptable (i.e. no further action would be required). In between the risks are tolerable provided ALARP.

For *Alternative 1*, a maximum of 290 fatalities could be expected, and the frequencies of these events occurring can be considered tolerable, provided ALARP. For *Alternative 2*, a maximum of 415 fatalities could be expected, and the frequencies of these events occurring are **Unacceptably High**. For both alternatives, the absolute worst-case scenarios have a likelihood of occurring once in 2.5 billion years.

Based on the above risks being in the ALARP range, eThekwini Municipality must ensure that they have implemented all reasonably practicable risk reduction measures in the design, construction, operation and maintenance of the new facilities.

The hazardous events contributing the most to the off-site residual risk are:

- Biogas gas holder catastrophic rupture
- Primary digester catastrophic rupture
- Secondary digester catastrophic rupture

Some possible risk reduction measures have been suggested in section 5.11.3.

There is currently no emergency procedure suitable for a Major Hazard Installation. The checklist shown in APPENDIX 7 can be used a guide for compiling procedures (refer to section 7 for details). In terms of the regulations, off-site emergency planning is the responsibility of the local authorities, with involvement from the operating personnel at the facility when developing the plan. Emergency services will be required to assist the site with the rescuing of any injured persons, applying first aid and medical treatment and providing an ambulance service to hospitals. They may also be required to warn and evacuate the public in the event of a large biogas release. Disaster Management may need to co-ordinate post incident support.

Given that this assessment has indicated potential off-site impacts it is important that Town Planning be made aware of the possible affected areas and the associated risks levels so as to manage the approval of developments in the vicinity of this Major Hazard Installation. If *Alternative 1* is chosen, not restrictions are foreseen. However if *Alternative 2* is chosen, the site's risks would already be breaching land-use planning guidelines.

3 Recommendations

The primary recommendations are:

- Notification to the authorities that the risk assessment has found that the proposed facilities will be Major Hazard Installations.
- SWWTW should proceed with the necessary MHI pre-construction notifications for the proposed facilities.
- This MHI risk assessment should be reviewed once construction is complete. Thereafter it should be reviewed within 5 years or sooner if significant changes are made to the risks posed by the site.

This risk assessment is issued by:

…………………………………

D C Mitchell Pr.Eng
Risk Assessor
ISHECONcc - Approved Inspection Authority as per APPENDIX 3.3 at the end of the report.
Date February 2015

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APPENDICES

1. INTRODUCTION

eThekwini Metro Water and Wastewater are responsible for the treatment of all municipal sewage in the greater eThekwini area. The Southern Waste Water Treatment Works (SWWTW) facilities process sewer effluent that is a combination of domestic and industrial in origin. It receives the majority of its raw sewage effluent through three large trunk sewers. SWWTW propose to begin treating the effluent instead of pumping it out to sea. A physical treatment process (through primary settling) will result in the organic load to sea being drastically reduced. The settled solids (referred to as primary (or raw) sludge) will then be removed and stabilised through a process of anaerobic digestion, before being dewatered. The biogas produced will be stored and likely utilised on site. SWWTW will refurbish and bring on-line a number of existing items of decommissioned processing equipment, as well as constructing new facilities. SWWTW requested an opinion on the classification the site as a Major Hazard Installation. The Classification study found that the site was indeed an MHI. This classification necessitates a full MHI Risk Assessment. This report summarizes the ISHECON MHI Risk Assessment review of 2014.

Several sections of the report necessitate substantiating information that 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 4.2, the appendix with the corresponding information will be numbered as appendix 4.2.

Although this assessment is based on the best available information and expertise, ISHECON cc cannot be held liable for any incident that may occur on this installation and associated equipment which directly or indirectly relate to the work in this report.

2. RECOMMENDATIONS

The following recommendations have been made

1. The facilities to be constructed during the proposed upgrade at Southern Waste Water Treatment Works should be considered a Major Hazard Installation as they have the potential to impact catastrophically on persons outside the site. (See section 5.6 and 5.7).

2. A copy of this risk assessment must be available on the site at all times for inspection by the relevant authorities. This assessment can be made available to interested or affected persons who may wish to scrutinize the document.

3. SWWTW/eThekwini Municipality should proceed with the necessary MHI pre-construction notifications for the proposed expansion/upgrade etc. (e.g. copies of this risk assessment to local Fire and Safety department, local labour centre, provincial director of department of labour, and department of labour chief inspector).

4. Public notification of the SWWTW expansion/upgrade and its MHI classification should be done by placing an advertisement in the local newspaper and by placing public notices in the area.

5. For both design alternatives, the individual risks posed to employees can be considered tolerable (Risk<1*10-3 d/p/y and >1*10-5 d/p/y) provided eThekwini Municipality has implemented all reasonably practicable risk reduction measures. See section 5.11.3 for risk reduction measures.

6. For *Alternative 1*, the individual risks posed to persons immediately outside the site are tolerable provided ALARP (Risk<$1*10^{-4}$ d/p/y and >$1*10^{-6}$ d/p/y) and risks posed to persons residing in residential areas nearby the site are acceptably low (Risk<$1*10^{-6}$ d/p/y).

7. For *Alternative 2*, the individual risks posed to persons immediately outside the site are **Unacceptably High** (Risk>$1*10^{-4}$). Risks posed to persons residing in residential areas nearby the site are acceptably low (Risk<$1*10^{-6}$ d/p/y).

8. Regarding societal risks, the maximum number of fatalities under worst-case conditions is expected to be 290 persons for *Alternative 1* and 415 persons for *Alternative 2*. The likelihood of these worst-case events occurring is around once in 2.5 billion years. Societal risks for *Alternative 1* remain in the tolerable provided ALARP range. However, societal risks for *Alternative 2* are **Unacceptably High**.

9. In terms of land-use planning restrictions, if Alternative 1 is chosen, no restrictions are foreseen. However if Alternative 2 is chosen, the site's risks would already be breaching land-use planning guidelines. (see section 5.11.4).

10. There is currently no emergency procedure suitable for a Major Hazard Installation. The checklist shown in APPENDIX 7 can be used a guide for compiling procedures (refer to section 7 for details).

11. eThekwini Municipality should confirm that the relevant local emergency services have a suitable off-site emergency plan in place, and should provide information and assistance where required in compiling such a plan.

12. eThekwini Municipality should familiarize themselves with the requirements of the MHI Regulation 7 in terms of incidents and near misses as well as activation of the MHI emergency plan that have to be recorded (records to be made available for inspection) and reported to the authorities.

13. This MHI risk assessment should be reviewed once construction is complete. Thereafter it should be reviewed within 5 years or sooner if significant changes are made to the risks posed by the site.

14. eThekwini Municipality should note that the MHI Regulations are under review at present and this may in future change the classification of the site and/or the requirements against the site.

3. ASSESSMENT METHODOLOGY

3.1 MHI REGULATION SCOPE OF APPLICATION

Refer to APPENDIX 3.1 for details.

The Major Hazard Installation Regulations under the Occupational Health and Safety Act of 1993 no. 85, revised in July 2001, [Ref 1] require that operators of all existing facilities conduct a risk assessment to determine the potential for causing major incidents (i.e. incidents that can affect the public outside the perimeter of the facility). This risk assessment will be used to assess whether or not there are sufficient emergency plans and equipment in place to deal with any such major incident, should it occur.

3.2 PHILOSOPHY FOR CLASSIFICATION AS AN MHI

See APPENDIX 3.2 for details.

An installation is classified as a Major Hazard Installation if:

- It is an installation where a hazardous substance that is listed in the General Machinery Regulations of the Occupational Health and Safety Act is processed, handled or stored and the content exceeds the quantity stipulated. Pressurized methane is a listed material with a threshold quantity of 15t. The largest single storage unit of methane at the SWWTW site is less than 2 tons (5000 m^3 primary digester, 60% of volume methane with a SG of 0.55kg/m^3). Therefore, the site would not be a compulsory MHI by this criterion.

- If a hazardous substance is not listed, or present in sufficient amounts for the site to be classified as above, there is a second clause in the legislation that must be considered. This clause indicates that if the installation has the potential to cause a major incident it is an MHI. A major incident is further defined as a catastrophe. A catastrophe is interpreted as affecting the public. Therefore, if there are potential incidents (e.g. gas releases, explosions or fires) that could generate effects that could lead to the death of a member of the public at the site boundary, it is considered a catastrophic event, and the site will be considered an MHI.

  For the purposes of this risk assessment, the areas within the SWWTW boundary wall, and within the fence around the water works, have been taken to be major hazardous premises. Therefore, the general public are those persons outside the sites (e.g. at neighbouring residences, as well as the public who make use of the roads and footpaths nearby). Any person entering either of the SWWTW site areas is deemed to be an employee or to have accepted the risks associated with entering the site.

- Assessors also consider whether a particular site would be classified as a Major Hazardous Site in the United Kingdom (UK). The COMAH legislation [Ref 7] in the UK is more prescriptive than the South African equivalent and provides a useful comparison. In addition, it is expected that should the MHI regulations change in future, they will most likely follow a system similar to the COMAH system. Once phase 2 of the upgrade is complete, and assuming all vessels/digesters are filled to capacity with only biogas, there could be a maximum possible inventory of 71500 m^3 (i.e. ±25 tons of methane). If this site were in Europe or the UK, it would not be considered an MHI Site. Natural gas (methane) is a named substance as per Part 2 of Schedule 1 of the COMAH Regulations. A site would need to have more than 50 tons of natural gas to be considered a LOWER TIER COMAH site. Those sites having more than 200 tons of would be UPPER TIER COMAH sites. The SWWTW site with a maximum inventory of ±25 tons of natural gas would not be considered a COMAH site.

3.3 ASSESSMENT PROCESS

The MHI regulations also stipulate that organisations commissioned to conduct the assessment be competent to express an opinion on the risks associated with the installation and be accredited as an Approved Inspection Authority. APPENDIX 3.3 contains details of ISHECON's accreditation.

Risk is made up of two components:

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

Therefore this assessment of risk comprises:

- Identification of the likely hazards and hazardous events expected to be associated with the operation of the installation.
- Quantification of the hazardous events in terms of their likely frequency.
- Quantification of the consequences of the hazardous events and their severity, should they occur.
- Estimation of the risk and comparison against certain acceptability criteria.

4 DESCRIPTIONS

4.1 DESCRIPTIONS OF ORGANISATION, LOCATION, SITE AND SURROUNDING HUMAN ACTIVITIES

4.1.1 ORGANIZATION

eThekwini Metro Water and Wastewater are responsible for the treatment of all municipal sewage in the greater eThekwini area. The SWWTW facilities process sewer effluent that is a combination of domestic and industrial in origin. It receives the majority of its raw sewage effluent through three large trunk sewers, with some lesser subsidiaries from local industry, as well as various smaller additional volumes of effluent discharged by road tankers.

4.1.2 LOCATION AND PHYSICAL ADDRESS

Figure 4.1.1 is a photo of KwaZulu-Natal southeast coast showing the location of SWWTW.

The installation's physical address is:

Southern Waste Water Treatment Works,
2 Byfield Road,
Merewent, Durban
KwaZulu-Natal

4.1.3 DESCRIPTION OF SITE AND SURROUNDINGS

Figure 4.1.2 is a map of the area showing the location of the SWWTW Southern Works facilities and relevant nearby features.

Figure 4.1.3 is a layout of the SWWTW Southern Works site, showing the features to be modified that are relevant to the MHI RA if Alternative One is chosen.

Figure 4.1.4 is a layout of the SWWTW Southern Works site, showing the features to be modified that are relevant to the MHI RA if Alternative Two is chosen.

On **Figure 4.1.2** the border of the SWWTW site (defined as the Major Hazard Installation Premises) is marked in thick red ink. For the purpose of this study all installations outside this area are considered to be neighbouring independent installations/developments.

As can be seen from these maps, there are many significant locations surrounding the site namely:

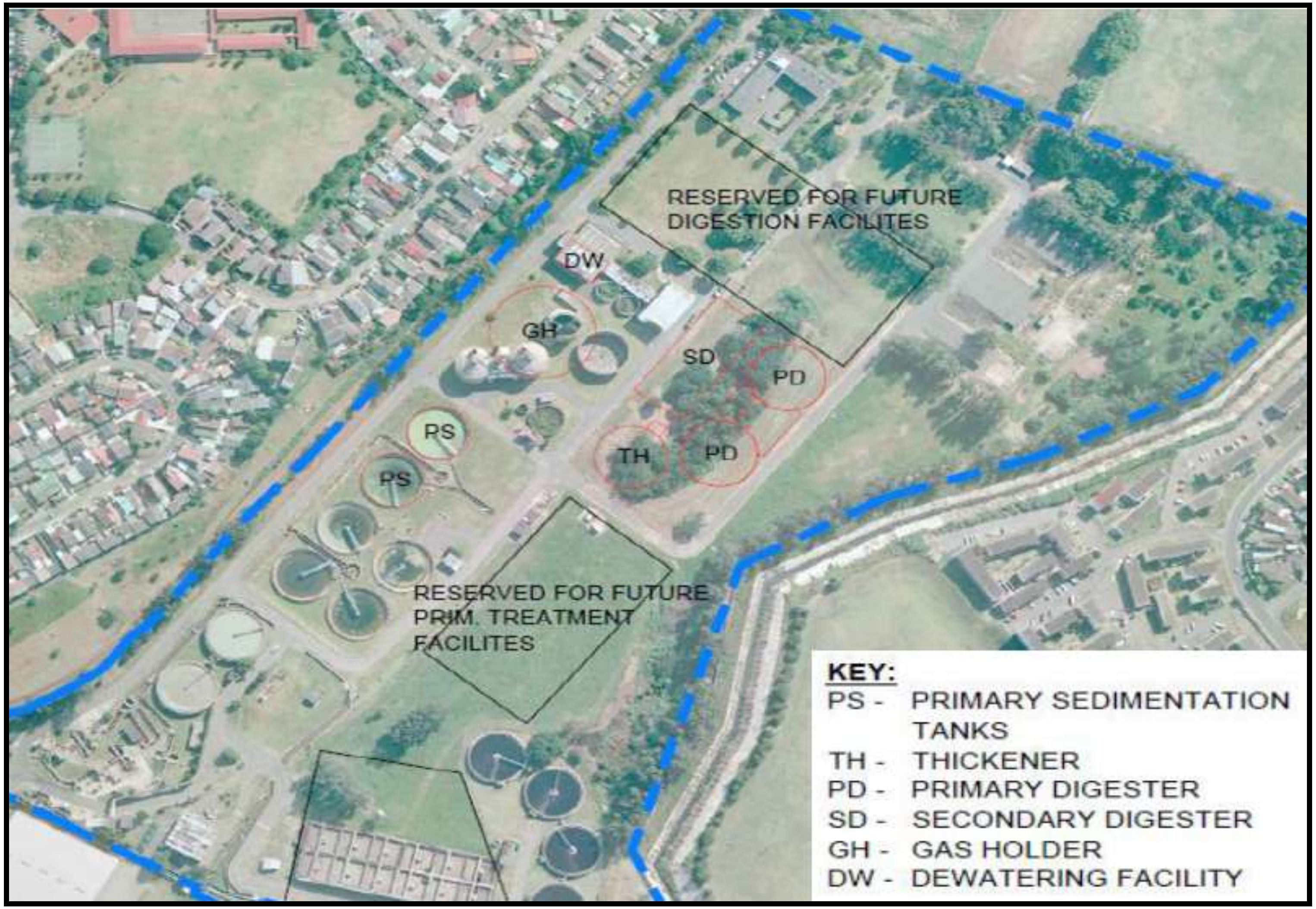
- The residential area of Merewent to the south east and northwest of the site. The nearest houses the MHI installations are situated on the northwest site boundary (±30m).
- Schools near the site are Merewent secondary school (200m north-west), Parsee Rustomjee primary school (300m north-west) and Settlers primary school (400m south-east)
- Industrial neighbours Mondi (±300m from nearest MHI installation) to the south and Engen (±450m) to the northeast of the site.

FIGURE 4.1.1 - Photo of KwaZulu-Natal south-east coast showing the location of SWWTW.

FIGURE 4.1.2 - is a map of the area showing the location of SWWTW facilities and relevant nearby features.

FIGURE 4.1.3 - is a layout of the SWWTW site, showing the features to be modified that are relevant to the MHI RA, if Alternative One is chosen.

FIGURE 4.1.4 - is a layout of the SWWTW site, showing the features to be modified that are relevant to the MHI RA, if Alternative Two is chosen.



4.2 *GEOLOGY, ECOLOGY AND METEOROLOGY*

4.2.1 GEOLOGY AND ECOLOGY

The area around the site is relatively flat sloping slightly down towards the dunes and ocean in the east. A small channel that runs into the sea is adjacent to the southern site boundary. The SWWTW forms part of the Durban Metropolitan Open Space System (DMOSS) and lies within the 1 in 100 year flood-line. The area is composed of a mixture of industrial and residential developments.
This is not an area of significant seismic activity.

4.2.2 METEOROLOGY

Meteorological conditions follow typical coastal weather patterns with night and early morning winds differing in direction. The dominant wind directions are either northeast or southwest, each for about 22 % of the time. Temperatures are generally high with limited seasonal or day / night variation. Humidity levels are also high all year round. Temperature inversions, which trap air in a stagnant layer near the earth surface, occur on winter nights.

Details of the weather conditions used in this study are presented in APPENDIX 4.2. The data is for the old Durban International Airport, which is nearby and can be applied to the site.

The emission distribution package used to simulate the dispersions of gases (PHAST RISK 6.7), focuses on the dominant weather conditions and as such does not consider the subtleties of local topography (such as hills and valleys) or local thermal conditions (such as upward currents due to heat generated by concentrated industries).

4.3 INSTALLATION PROCESS DESCRIPTION

The Southern Waste Water Treatment Works receives the majority of its raw sewage effluent through three large trunk sewers, with some lesser subsidiaries from local industry, as well as various smaller additional volumes of effluent discharged by road tankers.

The current practice is for all treated outflows to be discharged to sea. The aim of the proposed SWWTW upgrades is to reduce the quantity of suspended solids being disposed of to sea by affording primary treatment to the combined effluent discharges from two of the trunk sewers. This physical treatment process (through primary settling) will result in the organic load to sea being drastically reduced. The settled solids (referred to as primary (or raw) sludge) will then be removed and stabilised through a process of anaerobic digestion, before being dewatered.

ANAEROBIC DIGESTERS AND BIOGAS FACILITIES

Various process improvements are planned throughout the SWWTW plant, but the only changes to the primary and secondary treatment facilities that have bearing on the MHI RA are the refurbishment of the two primary digesters, the secondary digester and the gas holder, as well as the installation of additional anaerobic digesters, gas holders and a sludge dewatering facility which will utilise the methane rich biogas for heating to dry the sludge before transportation. The expansion is planned to take place in two phases. Phase one will be constructed presently, with phase two as a future project, the timing of which is uncertain.

Toxic releases of H_2S were considered in the classification study and found not to present MHI type consequences, and are thus not discussed further.

Alternative 1 - Phase 1

1. Refurbish and bring back on line two existing anaerobic primary digesters (5000m^3), as well as an existing secondary digester (4500m^3). Construct two new primary digesters and one new secondary digester, all of same capacity as the existing plant.
2. Refurbish and bring back on line an existing gas holder (4500m^3) and construct a new gas holder of the same capacity.
3. Establish a new mechanical sludge dewatering facility.

Alternative 1 - Phase 2

1. Construct four additional anaerobic primary digesters (5000m^3 each), as well an additional secondary digester (4500m^3).
2. Construct an additional gas holder (4500m^3).
3. Construct additional sludge dewatering facilities.

According to Environmental Impact Assessment (EIA) regulations, an alternative means of carrying out the treatment activities must be investigated and, as an alternative, SWWTW has proposed the following:

Alternative 2 - Phase 1

1. Demolition of the existing structures (primary and secondary digesters and gas holder).
2. Construct two primary digesters of 10000m^3 capacity each.
3. Construct a secondary digester of 9000m3 capacity.
4. Construct a gas holder of 9000m3.
5. Establish a new mechanical sludge dewatering facility as per Alternative 1.

Alternative 2 - Phase 2

The details of Phase 2 of this option have not been fully decided upon, but the following (worst-case, in terms of capacity) has been assumed

1. Construct two additional anaerobic primary digesters (10 000m^3 each), as well an additional secondary digester (9000m^3).
2. Construct an additional gas holder (9000m^3)
3. Construct additional sludge dewatering facilities

4.4 INVENTORIES OF MATERIALS

The following compounds (or groups of compounds) are used / produced / handled on the site. Note that only the largest or most hazardous (from an MHI perspective) materials are mentioned individually in this table, the rest are grouped together.

Material	Maximum Inventory (t)	Maximum Single Storage Unit (t)	Physical Form
Methane	Approximate combined storage: Primary Digesters: 5000 m^3 * 8 Digesters (±20% of vessel volume is normal storage, maximum is 100% biogas) =40 000 m^3 * 60% methane * SG of 0.55 = 13.2t Secondary Digesters: 4500 m^3 * 4 Digesters (±20% of vessel volume is normal storage, maximum is 100% biogas) =18 000 m^3 * 60% methane * SG of 0.55 = 6t Gas holders: 4500 m^3 * 3 Gas Holders =13 500 m^3 * 60% methane * SG of 0.55 = 4.5t Total: = ±25t	±5000 m^3 Primary digester =60 methane * 0.55 SG = 1.6t	Gas

Those materials present as solids are usually excluded from all Major Hazard Risk assessments on the grounds that they are EXTREMELY unlikely to come directly into contact with members of the public. The same applies to all liquids **EXCEPT** those that:

1) upon release, could form large clouds of toxic or flammable vapours or those
2) if inadvertently mixed, could generate toxic or flammable gases or those
3) if spilled and ignited could form huge pool fires or those
4) if spilled could spray or engulf persons outside the site in pools of corrosive liquid.

There remains only one manner in which the excluded solids and liquids could indirectly affect the public. If there is a large fire in the area, some of the materials could possibly combust to release hazardous compounds in the form of smoke.

For the materials stored in the general stores and workshops on site (e.g. minimal quantities of various brands of cleaning fluids, oils etc.), it is not practical (nor does it add significant value) to analyse each compound in detail with respect to its properties.

5 RISK ASSESSMENT

5.1 IDENTIFICATION OF HAZARDS

5.1.1 HAZARDOUS[1] MATERIALS ON THE SITE

The materials on the site were categorised according to SANS 10228:2003 [Ref. 2] classes of dangerous substances, as detailed below:

CLASS 1 - Explosives (covered by explosives act and not considered in MHI regulations)
CLASS 2 - Gases (only flammable or toxic gases could impact on the public)
CLASS 3 - Flammable liquids (these could form large pool fires, or release flammable vapour clouds)
CLASS 4 - Flammable solids (could contribute to warehouse fires etc.)
CLASS 5 - Oxidising substances and peroxides (possible explosions)
CLASS 6 - Toxic and infectious substances (only MHI if emit vapours that can affect persons outside the boundary, or liquids are extremely close to site boundary with no containment)
CLASS 7 - Radioactive materials (excluded from MHI, covered by other regulations)
CLASS 8 - Corrosives (generally not a major hazard unless very close to public at the boundary)
CLASS 9 - Miscellaneous, materials that are combustible and can lead to escalation of fires or toxic products of combustion

Materials that have the potential to cause harm (e.g. combustible, flammable, explosive or toxic).

	Gases or liquefied gases **CLASS 2**	Flammable Liquids **CLASS 3**	Flammable Solids **CLASS 4**	Oxidising substances **CLASS 5**	Toxic Vapours released from spill or mixing **CLASS 6**	Corrosives **CLASS 8**	Combustible with noxious decomp products or other CLASS 9	Potential MHI Issue (i.e. accidental impact off-site)
Biogas (containing methane ***)	Yes							**Yes**

In summary, there are compounds that have the potential to be the sources of major hazardous incidents.

Some critical properties of most of these compounds (or groups of compounds) are presented in APPENDIX 5.1.

5.1.2 ENVIRONMENTAL HAZARDS

Assessment of environmental impacts is not included in this Major Hazard Installation risk assessment, as it should be addressed in the EIA or EMP for the facility.

Note should be taken of the requirements of the new National Environmental Management Act (NEMA), which require various reports to be submitted in the event of any serious incidents on the installation. Safety, Health and Environmental management systems must be in place to facilitate the recording and reporting.

5.1.3 HAZARDOUS MATERIAL INTERACTIONS

There are no natural hazardous breakdown products of the materials as they are normally stored and used. During a fire scenario involving biogas, there will be highly noxious smoke possibly containing carbon monoxide and dioxide. These are however typical combustion products of almost any fire and present no major hazard threats.

5.2 INCIDENT AND ACCIDENT HISTORY

5.2.1 ACCIDENTS AT THIS SITE

There have been no MHI-type major accidents or incidents at the SWWTW site, as it was not previously an MHI with hazardous substances in significant amounts.

5.2.2 ACCIDENTS AT OTHER FACILITIES LOCAL AND INTERNATIONAL

Significant hazardous events have occurred at other similar or related installations around the world or with the expected MHI type materials that are used on site. The table in APPENDIX 5.2 summarises some of these events.

5.3 IDENTIFICATION OF POTENTIAL MAJOR HAZARDOUS EVENTS

The possibility of the following hazards were considered in the biogas processing and storage area:

- fire
    - external (jet, pool, flash)
- explosions
    - internal
    - confined within a building
    - unconfined
- acute toxic

Refer to APPENDIX 5.3 for a list of all the events considered as well as those finally selected for modelling in this assessment.

5.4 CAUSE ANALYSIS

5.4.1 TYPICAL CAUSES OF HAZARDOUS INCIDENTS

In order to quantify a hazard it is necessary to analyse in more detail the causes leading to the hazardous event.

Most hazards are due to loss of containment events. This is then followed either by ignition of the released flammable materials or dispersion of released toxic gas to areas where people may be exposed. It is also possible to have internal explosion events inside equipment.

Details of the typical causes of hazardous events are presented in APPENDIX 5.4.

5.4.2 PREVENTATIVE AND PROTECTIVE MEASURES

Associated with any events are measures that are usually in place to prevent it from occurring such as interlocks, trips. Once the initial failure has occurred there are other protective measures that are often in place to prevent escalation of the event (e.g. drench systems, emergency plans etc.). Details of the measures in place at eThekwini Municipality are presented with the plant design details in APPENDIX 4.3.

5.4.3 MHI TYPE INCIDENTS TO BE QUANTIFIED FOR MHI CLASSIFICATION OF THE SITE

All the incidents considered in this study are listed in the table in **APPENDIX 5.3.** Please note that this is not an exhaustive list of all incidents on the site that could impact on personnel. However, it represents most of the conceivable incidents that could possibly affect persons outside the site and therefore also possibly employees on site. From this list only the incidents that were qualitatively assessed (on the basis of the expected extent of the likely consequences) to be possible or probably major hazard incidents were further evaluated. **Table 5.4.3.1** presents some details of some typical MHI incidents that were quantified for MHI consequence analysis.

Plant Section	Event Incident	Causes	Consequences	Preventative Measures	Protective Measures (Mitigation – new systems)
Anaerobic digesters, gas holder, sludge dewatering building and biogas transfer piping.	Catastrophic rupture of vessel or piping	Over pressurization, mechanical failure, insufficient maintenance or impact damage.	Possible flash fire. Persons enveloped in flash fire suffer severe radiation injuries. Could also result in an unconfined vapour cloud explosion (UVCE), a blast over-pressure shockwave generated. Blast wave leads to damage to structures and injury to personnel and possibly public.	Maintenance and inspection of vessels and piping. No smoking on the site except in designated areas.	Emergency procedures. Firefighting equipment.
	Internal explosion inside vessel or building	Ingress of oxygen into vessel and ignition during maintenance, or leak of flammable gas into sludge de-watering building and ignition.	Explosion inside equipment/building ruptures equipment/building first (1-10% of energy). A blast over-pressure shock wave generated. Blast wave leads to damage to structures and injury to personnel and possibly public.	As above.	As above.

5.5 CONSEQUENCE ANALYSIS

5.5.1 MAGNITUDE OF SOURCE TERM

Information about two aspects of a loss of containment incident is required in order to determine the magnitude of a release; i.e. the rate at which the release occurs (or the size of the incident) and the duration of the release. See APPENDIX 5.5 for details.

5.5.2 DISPERSION MODELLING

For this study it is mostly the possible scenario of releases of flammable vapours that would require some dispersion modelling. Where applicable, condensed phase explosions are only slightly affected by the wind and weather conditions and dispersion modelling is not critical. For evaluation of the consequences of vapour dispersion incidents, PHAST RISK version 6.7 was used. Any vapour released from a source will form a cloud that will eventually disperse completely into the atmosphere. Generally, ground level concentrations will decrease as one moves further away from the source.

For this study gas dispersion modelling will not be further examined as the toxic effects of hydrogen sulphide were found not to extend beyond the site boundary.

5.5.3 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 shockwave 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 over-pressures and radiation levels that lead to specified degrees of harm are present in APPENDIX 5.5.

5.5.4 TOXIC RELEASES

There are no highly toxic gases or liquids present on this site in large enough quantities to result in lethal off-site effects.

5.6 SEVERITY ANALYSIS

Below are the consequence / severity modelling results for selected incidents (note information on all incidents can be made available on request) as well as the severity analysis outputs (i.e. measure of the lethality of the consequences). The series of plumes below show the different effects for releases of the contents of various different chemicals in vessels and piping under different wind and weather conditions.
Refer to the tables in the APPENDIX 5.5 in order to interpret the impact (damage) from the radiation and explosion circles below.

5.6.1 BIOGAS FIRES AND EXPLOSIONS

It is conceivable that there could be a significant accumulation of biogas vapours within the sludge de-watering building (e.g. due to biogas pipe leaks and inadequate ventilation), the gas boiler building or within the vessels when they are emptied for maintenance. Were these flammable environments to be ignited, a confined explosion could occur. The digesters, gas holders or biogas transfer pipes could also catastrophically rupture, propagating the ignition of the resultant vapour cloud, which would lead to an explosion or a flash fire. A rupture of the biogas transfer line, if immediately ignited, would result in a jet fire.

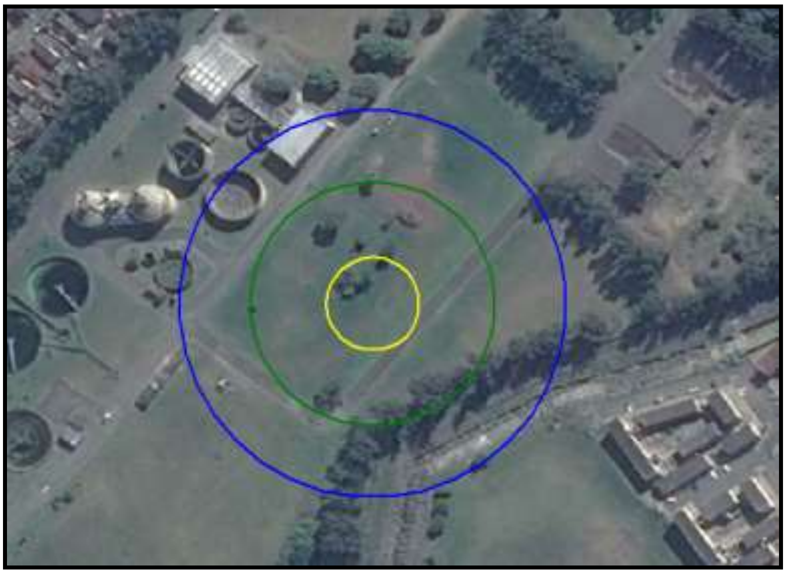
As a requirement of the EIA process, two possible design alternatives are being considered for this project, as described in Section 4.3 above. The consequences of loss of containment events for both Alternative 1 and Alternative 2 are compared below.

5.6.1.1.A Map showing overpressure circles from an internal explosion of a 5000m^3 anaerobic digester should there be ingress of a sufficient amount of oxygen and an ignition source (e.g. hot work). (Alternative 1)

- Yellow = 70kPa – Complete destruction (20m radius)
- Green = 14kPa - MHI threshold, 1% lethality (50m radius)
- Blue = 7kPa - Maximum extent of minor injuries (80m radius)

5.6.1.1.B Map showing overpressure circles from an internal explosion of a 10000 m^3 anaerobic digester should there be ingress of a sufficient amount of oxygen, and an ignition source (e.g. hot work). (Alternative 2)

- Yellow = 70kPa – Complete destruction (25m radius)
- Green = 14kPa - MHI threshold, 1% lethality (64m radius)
- Blue = 7kPa - Maximum extent of minor injuries (100m radius)



The consequences for Alternative 2 extend further, but this is negated by the fact that the digester is situated further from the site boundary.

5.6.1.2 Map showing overpressure circles from an internal explosion of the sludge dewatering facility should there be a leak and accumulation of biogas vapours. (Same for Alternative 1 and 2)

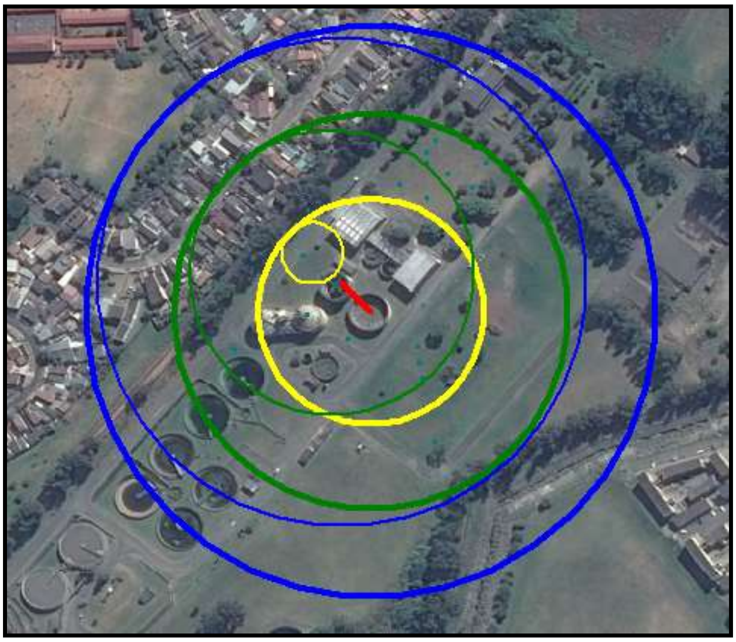
- Yellow = 70kPa – Complete destruction (10m radius)
- Green = 14kPa - MHI threshold, 1% lethality (27m radius)
- Blue = 7kPa - Maximum extent of minor injuries (42m radius)

This scenario is unlikely to have any real off-site effects, however it could result in on-site fatalities and thus preventative and protective measures must be considered.

5.6.1.3.A Map showing overpressure circles from delayed ignition after the catastrophic rupture of a 4500 m^3 gas holder releasing the entire contents. (Alternative 1)

Bold circles - maximum extent in any wind direction. Small faint circles - actual explosion for a SE wind.

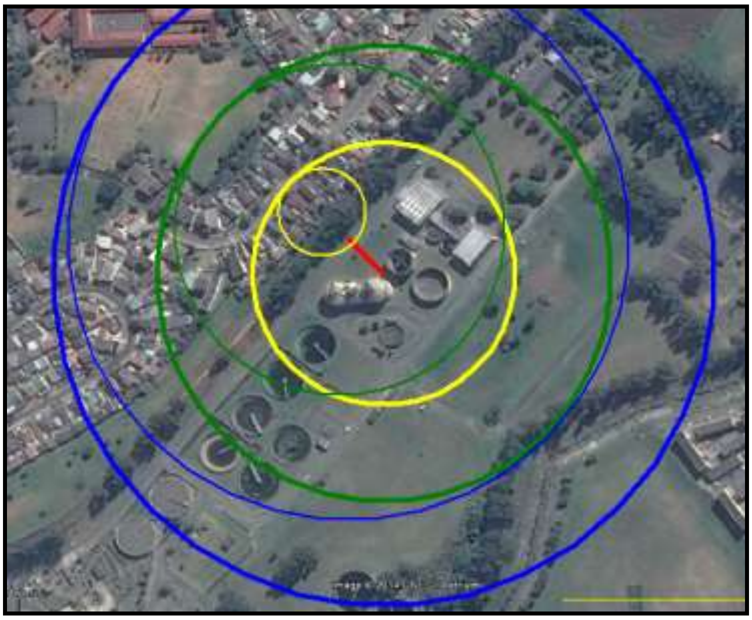
- Yellow = 70kPa - Severe damage (80m radius)
- Green = 14kPa - MHI threshold, 1% lethality (145m radius)
- Blue = 7kPa - Maximum extent of minor injuries (205m radius)



5.6.1.3.B Map showing overpressure circles from delayed ignition after the catastrophic rupture of a 9000 m^3 gas holder releasing the entire contents. (Alternative 2)

Bold circles - maximum extent in any wind direction. Small faint circles - actual explosion for a SE wind.

- Yellow = 70kPa - Severe damage (105m radius)
- Green = 14kPa - MHI threshold, 1% lethality (185m radius)
- Blue = 7kPa - Maximum extent of minor injuries (265m radius)



The consequences for Alternative 2 are far more severe than for Alternative 1. The "complete destruction" level of overpressure contour extends over the neighbouring residences and the 1% lethality zone extends 140m beyond the site boundary. The Alternative 2 scenario is by far the worst-case scenario that can originate on this plant.

5.6.1.4A Map showing flash fire from ignition of biogas release due to a biogas transfer pipe from the gas holder (4500m^3) to the sludge dewatering building rupturing. (Alternative 1)

Green = LFL level (7m radius)

Blue = 0.5 LFL (17m radius)

5.6.1.4B Map showing flash fire from ignition of biogas release due to a biogas transfer pipe from the gas holder (9000m^3) to the sludge dewatering building rupturing. (Alternative 2)

Green = LFL level (7m radius)

Blue = 0.5 LFL (17m radius)

The consequences for Alternative 1 and Alternative 2 are identical due to the size of the flash fire being determined by the rate of release and dispersion of the flammable cloud, which is the same in this case. As shown above, it is only the catastrophic events that have off-site effects. The smaller, more likely events do not extend off-site.

5.6.1.5A Map showing radiation levels a jet fire resulting from ignition of biogas release due to a biogas transfer pipe from the primary digester (5000m^3) to the gas holder rupturing. (Alternative 1)

- Green = 12.5kW/m^2 - MHI threshold, 1% lethality (6.5m radius)
- Blue = 4kW/m^2 - Maximum extent of minor injuries (15m radius)

5.6.1.5A Map showing radiation levels a jet fire resulting from ignition of biogas release due to a biogas transfer pipe from the primary digester (10 000m^3) to the gas holder rupturing. (Alternative 2)

- Green = 12.5kW/m^2 - MHI threshold, 1% lethality (7m radius)
- Blue = 4kW/m^2 - Maximum extent of minor injuries (16m radius)

As discussed in 5.6.1.4 above, the smaller, more likely pipe rupture scenarios do not have off-site effects.

5.7 MHI CLASSIFICATION AND NOTIFICATION

5.7.1 CLASSIFICATION

As can be seen from the discussion in the previous sections, it is expected that the various fire and explosion incidents could have impacts beyond the SWWTW site, and therefore the facility is classified as a **Major Hazard Installation**.
The table below indicates the distance to the 90% fatality and 1 % fatality thresholds for accidental events on site.

INCIDENTS	OPTION 1 DISTANCE TO MHI THRESHOLD (m)	DISTANCE TO SITE BOUNDARY (m)	MHI EVENT	OPTION 2 DISTANCE TO MHI THRESHOLD (m)	DISTANCE TO SITE BOUNDARY (m)	MHI EVENT
Primary digester internal explosion	50	33	**YES**	64	60	**Marginally**
Sludge Dewatering Facility Confined Explosion	27	25	**Marginally**	27	25	**Marginally**
Gas holder catastrophic rupture and delayed explosion	145	90	**YES**	185	60	**YES**
Biogas transfer piping rupture and flash fire	17	46	**NO**	17	46	**NO**

From the above table it is clear that the biogas installation could have off-site impacts and thus the SWWTW site should be classified as an MHI.

5.7.2 NOTIFICATION OF MAJOR HAZARD INSTALLATION

Note that this risk assessment already contains the following information as required by the Major Hazard Installation Regulations:

- A physical address of the installation.
- Envisaged maximum quantities of substances that resulted in the installation being classified as a Major Hazard Installation.
- MSDSs for the MHI materials on site. (APPENDIX 5.7)

A formal letter should be submitted notifying the local government, the Chief Inspector and the Provincial Director of the Major Hazard Installation that the risk assessment has been carried out. A copy of this risk assessment must accompany the letter particularly to the local authority emergency services. This must be done prior to construction of the new/upgraded facilities. Ideally public notification of the expansion should be undertaken and the 60-day comment period incorporated into the project schedule.

The risk assessment should be **updated after construction** and be reviewed again in 2019 (5 years), earlier if major modifications are made or the installations are expanded, as this could affect the risk.

5.7.3 REPORTING OF EMERGENCY OCCURRENCES

Since the site is a Major Hazard Installation; all incidents on the installation that require the emergency procedures to be activated must be reported to the local emergency services as well as to the Provincial Director of Labour. Such incidents must be recorded and the register must be available for inspection.

5.8 EFFECTS ON ADJACENT MAJOR HAZARD INSTALLATIONS (DOMINO EFFECTS)

At high levels of explosion over-pressure (70kPa) and fire radiation levels (37kWm^2) process equipment integrity can be expected to be adversely affected. There are no other declared Major Hazard Installations in the immediate vicinity and therefore domino effects are not a concern. It is however noted that the worst-case events at the biogas installation could possibly damage other biogas facilities, possibly leading to secondary fires or explosions.

5.9 LIKELIHOOD OF MAJOR HAZARDS

To determine the likely frequency of occurrence of MHI-type events, generic failure data was used, as well as data available from the site or similar sites.

The standard failure data used for these types of failures was adjusted to account for the assessor's evaluation of the effectiveness of the 'systemic organizational factors' in operation on site (i.e. the level of maintenance and housekeeping, as well as how effective the actual implementation of any safety management system is etc.). The site was evaluated using a checklist and found to be well-maintained and organised with good awareness of process safety principles. As is done for most sites pre-construction (since the site is not yet an MHI and thus the MHI-type organizational measures are not in place yet) a fairly conservative rating (equivalent to a site having slightly more than the "bare minimum" organizational measures in place) was given to the site and thus failure data was negatively adjusted. This should be re-assessed during the post-construction MHI RA.
NOTE - Two sets of failure data figures are shown below. Column A is based on the failure rates for the equipment stipulated in Phase 1 & 2 of Alternative 1 and Column B is the failure rates for equipment to be included in Phase 1 & 2 of Alternative 2.
Details of the failure data used and the final failure frequencies used are in APPENDIX 5.9.

TABLE 5.9.1 – FREQUENCY DATA

EVENT	Alternative 1 (Events/yr)	Alternative 2 (Events/yr)
1. PRIMARY DIGESTER INTERNAL EXPLOSION	**4.00E-04**	**2.00E-04**
2. PRIMARY DIGESTER CATASTROPHIC RUPTURE	**2.00E-04**	**1.00E-04**
3. SECONDARY DIGESTER INTERNAL EXPLOSION	**2.00E-04**	**1.00E-04**
4. SECONDARY DIGESTER CATASTROPHIC RUPTURE	**1.00E-04**	5.00E-05
5. BIOGAS GAS HOLDER CATASTROPHIC RUPTURE	7.50E-05	5.00E-05
6. BIOGAS GAS HOLDER INTERNAL EXPLOSION	**1.50E-04**	**1.00E-04**
7. BIOGAS TRANSFER LINE FROM DIGESTER TO GAS HOLDER RUPTURE	**4.00E-04**	**2.00E-04**
8. BIOGAS TRANSFER LINE TO SLUDGE DE-WATERING BUILDING RUPTURE	7.50E-05	7.50E-05
9. DRYING ROOM INTERNAL EXPLOSION	7.50E-05	7.50E-05

Events in **BOLD** have a high likelihood of occurrence and in **BOLD RED** a very high likelihood.

* Note 1E-06 is equal to 1 * 10^{-6} or one in a million

5.10 RISK LEVELS

Two types of risk were evaluated in this risk assessment. They are discussed briefly below and more details are presented in APPENDIX 5.10. Use was made of the computer model DNV PHAST RISK 6.7 (previously SAFETI) to obtain the risk results.

NOTE: The two different design options have different individual and societal risks associated with them. See **Figures 5.10.2 and 5.10.4** to see Alternative 2's risk levels for comparison.

5.10.1 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 the order 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 account of the total number of people at risk from a particular event, nor does it account for 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 5.10.1** for all relevant 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).

5.10.2 SOCIETAL RISK

Individual risk referred to above considers the risk to a typical individual but does not consider how many individuals could be affected. In general communities have an aversion to large events that 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 these accidents on the 'x-axis'

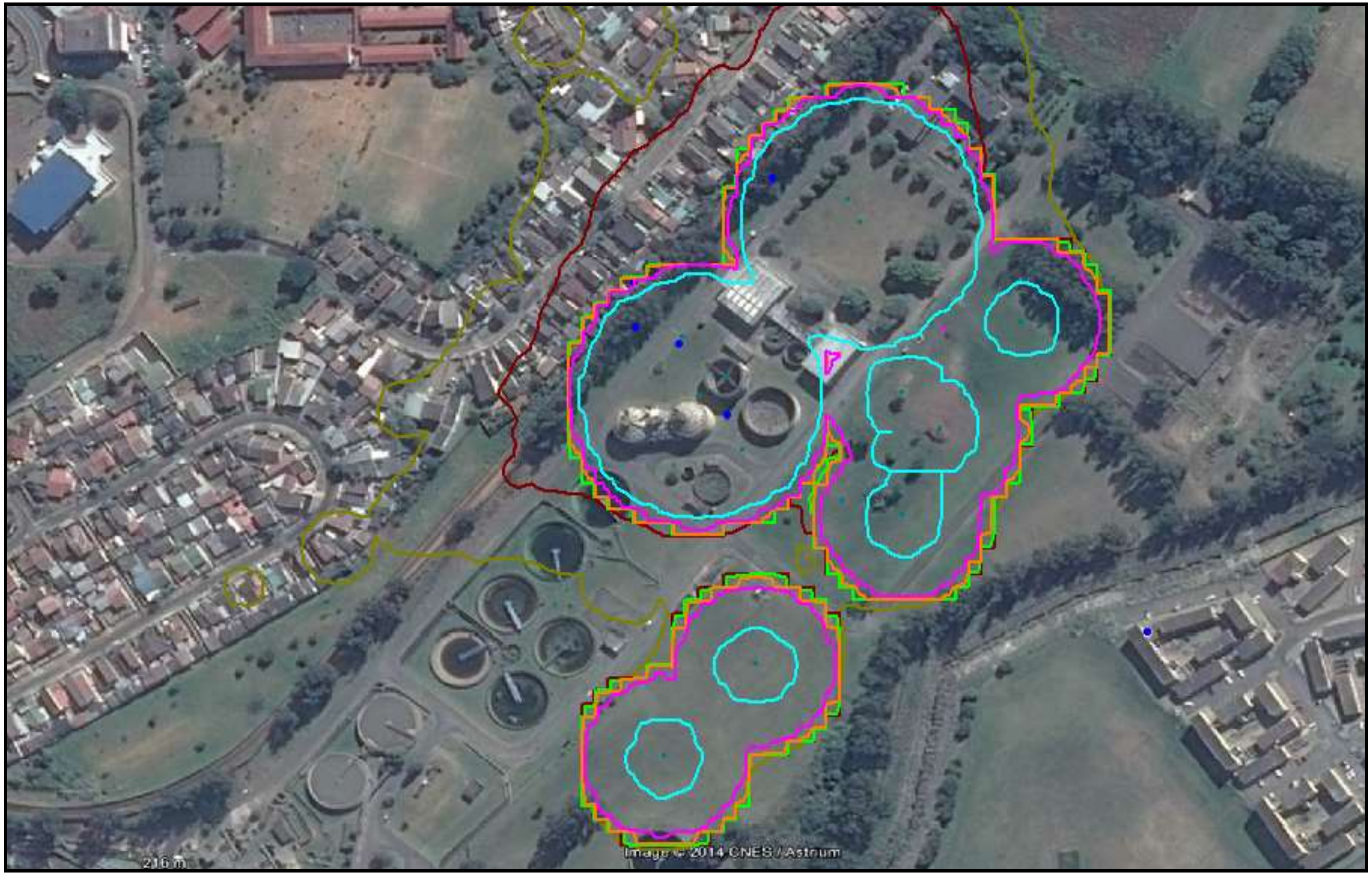
Societal risk: This includes the population in the vicinity and estimates the chances of numbers of people being harmed from an incident. The likelihood of the primary event (an accident at a major hazard plant) is still a factor, but the consequences are assessed in terms of level of harm and numbers 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 APPENDIX 5.10 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 each and every one of the potential events on site against the frequency with which these levels of fatalities can be expected to occur.

See **Figure 5.10.3** below.

FIGURE 5.10.1 – Individual Risk Isopleths for the SWWTW if <u>Alternative 1</u> is used.
(Blue= 1e-4, pink= 1e-5, orange=1e-6, green=1e-7, etc.)

No red risk contours should be present within the site – as there are not, **on-site risks are tolerable provided ALARP.**
The light blue lines **must not** extend beyond the site boundary – as they do not, **off-site risks are tolerable provided ALARP.**

FIGURE 5.10.2 – Individual Risk Isopleths for the SWWTW if <u>Alternative 2</u> is used.
(Blue= 1e-4, pink= 1e-5, orange=1e-6, green=1e-7)



No red risk contours should be present within the site – as there are not, **on-site risks are tolerable provided ALARP.**

The light blue lines **must not** extend beyond the site boundary – as they do, **off-site risks are UNACCEPTABLY HIGH.**

FIGURE 5.10.3 – Societal Risk F-N Curve for the SWWTW if <u>Alternative 1</u> is used.

The blue and green lines for the installation risk **must not** be above the yellow risk criteria line and ideally below the red line – societal risks are **Tolerable Provided ALARP.**

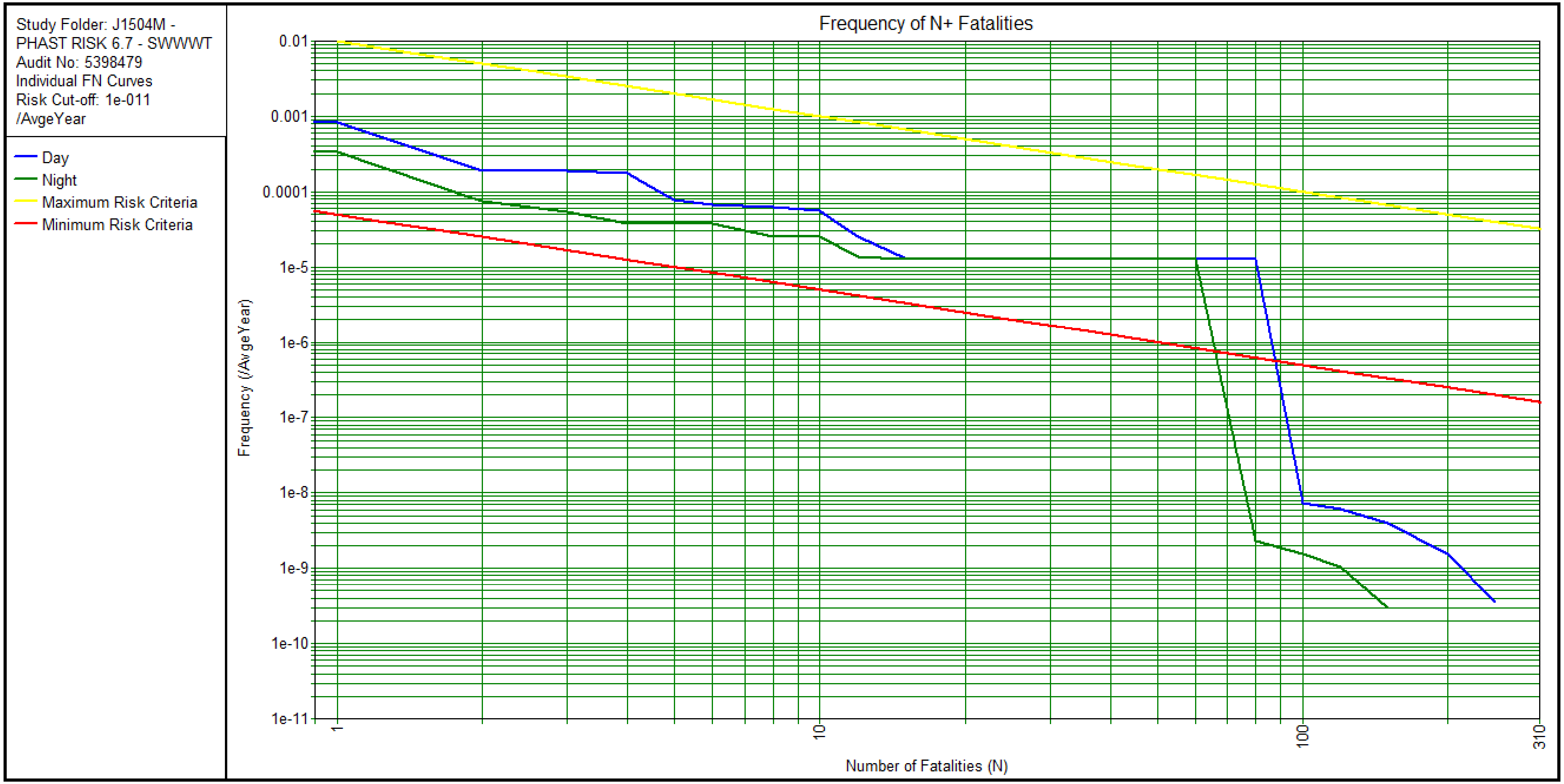
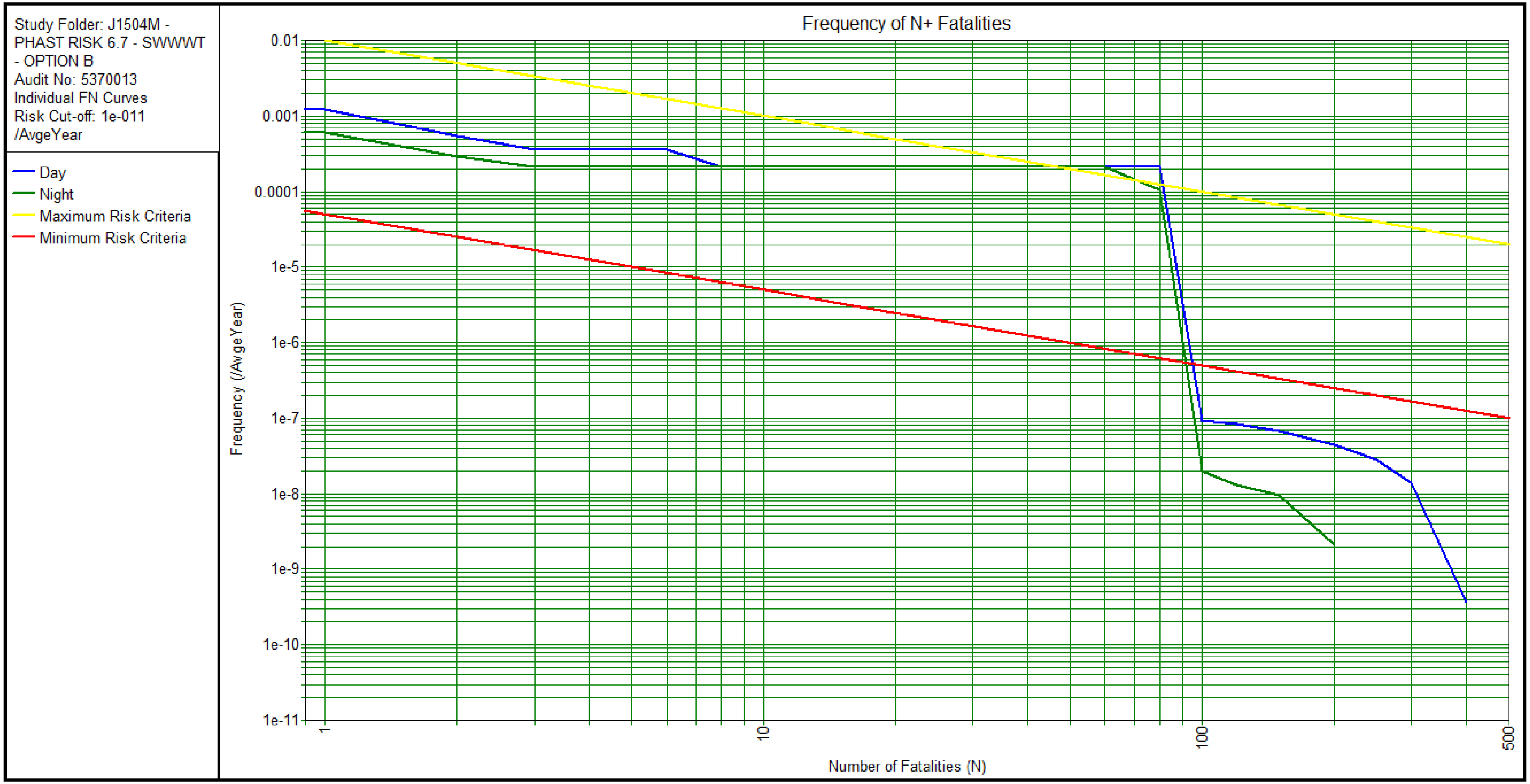


FIGURE 5.10.4 – Societal Risk F-N Curve for the SWWTW if <u>Alternative 2</u> is used.

The blue and green lines for the installation risk **must not** be above the yellow risk criteria line, and ideally below the red line – societal risks are **Unacceptably High.**



5.11 RISK ACCEPTABILITY

5.11.1 INDIVIDUAL RISK

With respect to acceptability of risk, there are no agreed (or legislated) numerical criteria applicable in South Africa. In the absence thereof it is believed that the use of the United Kingdom's Health and Safety Executive's criteria will prove justifiable. These criteria are well-developed, conservative and yet not stringent to the point of inhibiting industrial development. See APPENDIX 5 Section11 for a discussion on the acceptability of risk and the UK criteria.

SUMMARY OF UK HSE INDIVIDUAL RISK CRITERIA

	INSTALLATION EMPLOYEES	**TYPICAL PUBLIC PERSONS**[1]
UNACCEPTABLY HIGH INDIVIDUAL RISK	**1000** chances in a million (cpm) of being fatally affected in any one year or 1 * 10^{-3}	**100** chances in a million (cpm) of being fatally affected in any one year
BROADLY ACCEPTABLY LOW INDIVIDUAL RISK	**10** chances in a million (cpm) of being fatally affected in any one year	**1** chance in a million (cpm) of being fatally affected in any one year

[1] – public persons are any persons outside the boundary of the site, e.g. employees of neighbouring installations, residents, passers-by etc.

The table below presents some of the risk levels at key locations near the site. The table also indicates the events that contribute the most to the residual risks. It should be noted that the residual risks are the unmitigated risks (i.e. they assume a potentially exposed individual is at the location 24 hrs. a day and cannot escape).

LOCATION	INDIVIDUAL RISK LEVEL (per million)	ASSESSMENT PER UK HSE CRITERIA	INDIVIDUAL RISK LEVEL (per million)	ASSESSMENT PER UK HSE CRITERIA	EVENTS CONTRIBUTING TO THE RESIDUAL RISK (OPTION 1)
Onsite Risks					
	Alternative 1		**Alternative 2**		
Near Exist Gas Holder	75	Tolerable Provided ALARP	210	Tolerable Provided ALARP	• 5. BIOGAS GAS HOLDER CATASTROPHIC RUPTURE • 2. PRIMARY DIGESTER CATASTROPHIC RUPTURE • 4. SECONDARY DIGESTER CATASTROPHIC RUPTURE
Road Near Dewatering Facility	175	Tolerable Provided ALARP	360	Tolerable Provided ALARP	• 9. DRYING ROOM INTERNAL EXPLOSION • 4. SECONDARY DIGESTER CATASTROPHIC RUPTURE
Off-site Risks					
	Alternative 1		**Alternative 2**		
At NW Site Boundary	0.002	Acceptably Low	**210**	**Unacceptably High**	• 2. PRIMARY DIGESTER CATASTROPHIC RUPTURE • 5. BIOGAS GAS HOLDER CATASTROPHIC RUPTURE
Nearest House (NW)	0.002	Acceptably Low	0.07	Acceptably Low	• 5. BIOGAS GAS HOLDER CATASTROPHIC RUPTURE • 2. PRIMARY DIGESTER CATASTROPHIC RUPTURE • 4. SECONDARY DIGESTER CATASTROPHIC RUPTURE
Nearest House (S)	-	No risk	-	No risk	• N/A
House across Sambalpur Road (N)	0.00006	Negligible	0.01	Acceptably Low	• 5. BIOGAS GAS HOLDER CATASTROPHIC RUPTURE • 2. PRIMARY DIGESTER CATASTROPHIC RUPTURE • 4. SECONDARY DIGESTER CATASTROPHIC RUPTURE

From the above table the following aspects can be highlighted:

Alternative 1

- The unmitigated individual risks posed to employees on the SWWTW site working near the biogas installations can be considered tolerable, provided all reasonably practicable risk reduction measures have been implemented (i.e. Risk< $1*10^{-3}$ d/p/y and >$1*10^{-5}$ d/p/y).

- The unmitigated individual risks posed to persons outside the SWWTW site at the nearest (NW) site boundary are tolerable provided ALARP (i.e. Risk< $1*10^{-4}$ d/p/y and < $1*10^{-6}$ d/p/y),

- The unmitigated individual risks posed to persons in the nearest houses in the residential area adjacent to the site are acceptably low (i.e. off-site risk < $1 * 10^{-6}$ d/p/y).

(

- The unmitigated individual risks posed to persons living in the houses across Sambalpur road in the residential area adjacent to the site are negligible (i.e. off-site risk < $1 * 10^{-9}$ d/p/y).

Alternative 2

- The unmitigated individual risks posed to employees on the SWWTW site working near the biogas installations can also be considered tolerable provided all reasonably practicable risk reduction measures have been implemented (i.e. Risk< $1*10^{-3}$ d/p/y and less than $1*10^{-5}$ d/p/y).

- The unmitigated individual risks posed to persons outside the SWWTW site at the nearest (NW) site boundary are **Unacceptably High** (i.e. Risk> $1*10^{-4}$ d/p/y).

- The unmitigated individual risks posed to persons in the nearest houses in the residential area adjacent to the site, are also acceptably low (i.e. off-site risk < $1 * 10^{-6}$ d/p/y).

- The unmitigated individual risks posed to persons living in the houses across Sambalpur road in the residential area adjacent to the site are not negligible as for Alternative 1 above, but merely acceptably low (i.e. off-site risk < $1 * 10^{-6}$ d/p/y).

5.11.2 SOCIETAL RISK

Figure 5.10.3&4 indicate that the daytime risks are much higher than the nighttime risks. This is due to the influx of additional employees into the area during the day.

The maximum number of fatalities under worst-case conditions is expected to be 290 persons for Alternative 1, and 415 persons for Alternative 2. The likelihood of these worst-case events occurring is around once in 2.5 billion years.

Societal risks for Alternative 1 remain in the tolerable provided ALARP range. However, societal risks for Alternative 2 are **Unacceptably High**.

If one were to exclude employees at SWWTW from the risk calculations, the societal risk posed to persons outside the site boundary would be somewhat reduced. However, employees can only be excluded if a formal Occupied Building Study has been done and it has been established that sufficient protection against fire, explosions and toxic releases have been provided for employees. There are standards and guidelines for such studies.

As no such study has been done, risk calculations at this site must include employees and thus the societal risks can only be considered tolerable provided ALARP.

5.11.3 RISK REDUCTION MEASURES

Given the above-mentioned tolerable provided ALARP risk levels, risk reduction measures should be investigated and those that are reasonably practicable should be implemented. This MHI report will suggest that certain risk reduction measures be considered, however these will merely be suggestions that eThekwini Municipality is responsible for investigating further. SWWTW should undertake their own risk reduction study and then implement those measures that are deemed reasonably practicable. Some possible improvements could include:

- Ensuring the maintenance and testing of protective measures. Any methane detectors that are installed around the plant must be regularly tested and calibrated.
- Consider erecting an additional windsock near the AD plant that would be clearly visible to the staff at this far side of the site.
- Since biogas is both flammable and toxic -and is being newly introduced onto the site- SWWTW must ensure that all plant staff are fully aware of the hazards associated with the plant.
- SWWTW should also take note that the empty vessels (digesters, piping, gas holders) must be thoroughly purged before entry/hot work and a hot work permit system must be put into place if there isn't yet one. Consider reviewing the plant SOP's in light of this change.
- Consider installing methane detectors at key locations on the site, especially at the NW boundary near the residential area.
- SWWTW must ensure that they have adequate means for firefighting. The need for adequate firewater, at the required pressure, back-up fire water pumps, a fire team and their training and the emergency response plan must all be reviewed. See the checklist in APPENDIX 8 for a more comprehensive list of measures that can be taken.

Note that risks can never be neglected and continued efforts should always be made to reduce the risks through improved management systems, emergency procedures, maintenance programs etc. Any measures implemented to reduce off-site risks would simultaneously reduce on-site risks.

5.11.4 LAND USE PLANNING IN THE VICINITY OF MHI's

There is a twofold responsibility placed on the local authorities when dealing with an MHI (See MHI regulation 9). Initially they should ensure that the existing MHI 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 (e.g. they should act to prevent of erection of hospitals very close to Major Hazard Installations).

In terms of land-use planning restrictions, if Alternative 1 is chosen, no restrictions are foreseen. However, if Alternative 2 is chosen, the site's risks would already be breaching land-use planning guidelines.

Note that the above are merely suggestions and any decisions regarding land use planning are entirely the responsibility of the local authorities.

6 ENVIRONMENTAL ISSUES

There are no specific major hazard environmental issues related to the functioning of this Major Hazard Installation.

7. EMERGENCY PLAN

7.1 ON SITE EMERGENCIES

These can be emergencies that result from a fire, an explosion and toxic releases which usually only have an effect on the installation itself and any other surrounding installations within the boundaries of the site. There is currently no suitable emergency procedure for a Major Hazard Installation. The checklist shown in APPENDIX 7 can be used a guide for compiling procedures.

These on-site emergency procedures need to be reviewed and updated every 3 years. In addition, the procedures must be tested and practised once a year and a record must be kept. This needs the involvement of local emergency services and any other industries in the area which may be affected.

Finally, the owner or employer (Chief Executive Officer or designate) must sign the site emergency procedure.

7.2 OFF SITE PUBLIC EMERGENCIES

SWWTW should communicate with the local emergency services to ensure that a suitable off-site emergency plan is in place for the installation (see MHI Regulation 9). The off-site plan is the responsibility of the local authorities.

In terms of MHI Regulation 7 there is a requirement for SWWTW to record and report to the relevant national, provincial and local authorities, any major incidents, incidents which brought the emergency plan into action, as well as near-misses. The records must be available on the site for inspection.

8. ORGANIZATIONAL MEASURES

It is obviously good practice for MHI operating companies to put in place organisational measures with the aim of preventing risk events that could result in a MHI incident. Such organisational measures are known as a 'process safety management system' and cover elements such as: management leadership; safety documentation; integrity assurance; instrumented protection functionality; mechanical protective systems; electrical protective systems; process protective systems etc.

In APPENDIX 8 is a checklist that can be used to review the Organizational Measures in place on the site with the specific focus on MHI type process safety hazards (e.g. the control of modifications, testing of trips and alarms etc.).

9. CONCLUSIONS AND DISCUSSION

The 2014 Major Hazard Installation Risk Assessment review of the expanded/upgraded SWWTW facilities has drawn the following conclusions:

1. The facilities to be constructed during the proposed upgrade at Southern Waste Water Treatment Works should be considered a Major Hazard Installation as they have the potential to impact catastrophically on persons outside the site. (See section 5.6 and 5.7).

2. SWWTW/eThekwini Municipality should proceed with the necessary MHI pre-construction notifications for the proposed expansion/upgrade etc. (e.g. copies of this risk assessment to local Fire and Safety department, local labour centre, provincial director of department of labour and department of labour chief inspector).

3. For both design alternatives, the individual risks posed to employees can be considered tolerable (Risk<$1*10^{-3}$ d/p/y and >$1*10^{-5}$ d/p/y) provided eThekwini Municipality has implemented all reasonably practicable risk reduction measures. See section 5.11.3 for risk reduction measures.

4. For *Alternative 1*, the individual risks posed to persons immediately outside the site are tolerable provided ALARP (Risk<$1*10^{-4}$ d/p/y and >$1*10^{-6}$ d/p/y) and risks posed to persons residing in residential areas nearby the site are acceptably low (Risk<$1*10^{-6}$ d/p/y).

5. For *Alternative 2*, the individual risks posed to persons immediately outside the site, are **Unacceptably High** (Risk>$1*10^{-4}$). Risks posed to persons residing in residential areas nearby the site are acceptably low (Risk<$1*10^{-6}$ d/p/y).

6. Regarding societal risks, the maximum number of fatalities under worst-case conditions is expected to be 290 persons for *Alternative 1*, and 415 persons for *Alternative 2*. The likelihood of these worst-case events occurring is around once in 2.5 billion years. Societal risks for *Alternative 1* remain in the tolerable provided ALARP range. However, societal risks for *Alternative 2* are **Unacceptably High**.

7. In terms of land-use planning restrictions, if Alternative 1 is chosen, not restrictions are foreseen. However if Alternative 2 is chosen, the site's risks would already be breaching land-use planning guidelines. (see section 5.11.4).

8. There is currently no emergency procedure suitable for a Major Hazard Installation. The checklist shown in APPENDIX 7 can be used a guide for compiling procedures (refer to section 7 for details).

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APPENDICES

APPENDIX 3

3.1 THE MAJOR HAZARD INSTALLATION REGULATIONS

3.2 CLASSIFICATION AS A MAJOR HAZARD INSTALLATION

3.3 RISK ASSESSMENT PROCESS

3.1 THE MAJOR HAZARD INSTALLATION REGULATIONS

During the 1970's and 80's there were many catastrophic events around the world related to the large scale production and storage of hazardous chemicals, e.g. Flixborough, Bhopal, Seveso, Mexico City to name a few. Many public persons outside the actual chemical sites were adversely affected by explosions, fires and the release of toxic gases. In many cases (e.g. Bhopal) this was compounded by the fact that the public as well as the emergency services had no idea of the types of chemicals on the sites and therefore no idea of how to respond when the events occurred. In some cases (Bhopal and Mexico City) the situations were compounded by the fact that residential developments (particularly low cost or informal settlements) had been allowed to develop right next door to these chemical factories.

In an attempt to prevent the reoccurrence of such disasters there was a trend in the 1980's and 90's around the world to implement legislation to control such situations. The so called Seveso Directives in Europe and their implementation in the United Kingdom as the CIMAH and COMAH regulations are a good example of how these laws have been implemented.

When the first round of legislation was published in Europe the focus was on getting companies to notify, i.e. the government and interested and affected parties now knew where the installations were. The second round of legislation required companies to perform risk assessments of their operations and to submit these for scrutiny to the authorities. The most recent round of legislation is focussed on requiring companies to provide evidence that they are managing their risks adequately.

When the South African laws were compiled, the authors took cognisance of the regulations in other countries and any difficulties that had been experienced. The regulations tried to address these difficulties. For example in Europe there was a tendency for some companies to keep just less than the threshold quantities to avoid having to comply. For this reason the South African legislation does not set a lower limit on the quantities of substances that must be considered.

Ultimately the objective behind registering a site as a MHI is to ensure that the local authorities know what hazardous chemicals and hazards are out there, have emergency plans in place in case of an incident and have adequate information to control developments to suit e.g. planning a suitable school, hospital or old age home near a hazardous chemical site. Companies are also better equipped to know what their risks are and can manage them accordingly.

The Major Hazard Installation Regulations falling under the Occupational Health and Safety Act of 1993, were promulgated on 16 January 1998. Although these regulations were revised in July 2001, the fundamental requirements remain in force [Ref. 1].

Part of these regulations require existing facilities and all new facilities, who have hazardous materials on their sites, to conduct a risk assessment to indicate their potential for causing major hazardous events (i.e. hazardous events of catastrophic proportions that can affect employees and the public outside the perimeter of the facility). This risk assessment must be reviewed every 5 years.

The risk assessment, which indicates why the installation is a major hazard installation, must then be presented to the National, Provincial and Local Authorities. The authorities have a responsibility to ensure suitable risk levels and separation distances between new installations, new residential developments, sensitive areas such as hospital etc. The public in the area of an MHI must be notified and for new installations persons have 60 days to make submissions to the relevant authorities.

The regulations are not prescriptive in terms of the classification of MHIs. Should anything occur which does indeed impact on the general public; the onus will lie with the management of the facility to prove why the installation is not classified as a major hazard and why the associated precautions / plans etc. were not implemented.

In South Africa there is other legislation (i.e. other regulations under the OHS Act) that govern assessment of hazards for employees. There is also legislation for environmental effects inside and outside a facility. Therefore the focus of the MHI regulations is on the direct physical and chemical impacts of chemical installations on the public at large. An MHI assessment is therefore not a detailed audit of all the possible risks to plant equipment and operating personnel etc., but focuses rather on those hazardous events that could have a "significant" impact outside the installation boundary. Long terms environmental aspects (e.g. ground water contamination) and long term health hazards (e.g. carcinogens) are therefore not within the scope of MHI considerations.

Terms frequently used in this report and the interpretation / meaning attached to each of these terms can be found in the Major Hazard Installation regulations.
Definitions of some other terms are listed below.

Hazard	A situation that has the potential to harm people, the environment or physical property, through a fire, explosion or toxic release, e.g. the use, storage or manufacture of a flammable or toxic material;
Hazardous Incident or Event	An occurrence due to use of plant or machinery or from activities in the workplace, that leads to an exposure of persons to hazards, e.g. the rupture of a vessel and loss of containment of flammable or toxic material (also referred to as a hazardous event);
Causative events	Occurrences that give rise to a hazardous incidents, e.g. failure of a temperature indicator or pressure relief, etc.;
Consequences	The physical effects of hazardous incidents and the damage caused by these effects;
Severity	The seriousness of the consequences, e.g. death or injury or distress;
Risk	The overall probability of a particular type of consequence of a particular type of incident affecting a particular type of person;
Acceptability	The evaluation of the risk in comparison to certain known level of risk in other areas;

3.2 CLASSIFICATION AS A MAJOR HAZARD INSTALLATION

An installation is classified as a major hazard installation if:

1. More than the prescribed quantity (as per Schedule A in the General Machinery Regulations under the OHS Act [Ref. 1]) of any substance is kept on site in one fixed vessel.

2. Where the form and quantity of any substance is such that it has the potential to cause a major incident i.e. an incident of catastrophic proportions.

   This classification therefore rests on defining what are considered to be 'catastrophic' consequences of major incidents. There is no clear definition and the interpretations can vary widely. ISHECONcc have adopted an interpretation which declares in this context that:

> *"A catastrophe constitutes any hazardous event which exposes members of the public to harmful effects of such a magnitude that a typical healthy adult would suffer some adverse health effects and a more vulnerable person could possibly be fatally injured."*

The above interpretation is converted into a consequence-based quantification criterion of 1% chance of fatalities from major hazardous events.

The focus of the legislation is on immediate acute effects due to hazardous chemicals. Therefore, only hazardous chemicals are considered and not the effect, for example, of hot high pressure water or the potential energy in elevated water storage structures etc. If a material is not listed as hazardous in the South Africa Legislation (i.e. SANS 10228 [Ref. 2]) or in international databases such as materials safety datasheets, then it is not consider as contributing to a potential major hazard under this legislation. As there is other legislation (Environmental and Health legislation) governing chronic exposure to chemicals and long term health effects (e.g. carcinogens) this is also not included in MHI classifications.

If there are potential incidents (e.g. gas releases, explosions or fires) that could generate effects at the site boundary but the magnitude of the effects are less than any of the levels of consequences listed below, then the installation is clearly NOT a major hazard installation (i.e. fatalities are not expected). Although there would be effects, they are not considered significant enough to be catastrophic:

- Thermal radiation from fires: 4 kW / m^2 for 1 minute [severe injuries, but no fatalities e.g. blistering of skin, second degree burns] as per *API 521* [Ref 3] this is tolerable for a few minutes without protection. This is also a World Bank Standard [Ref 4] for what is considered potentially painful but not lethal.

- Blast overpressure from explosions: 7 kPa [building damage, may be uninhabitable, injuries from glass etc but no direct fatalities] as per UK *HSE* consultation distances for developments [Ref 5].

- Toxic gas dose: ERPG 2 concentration for 1 hour (Emergency Planning Response Guidelines [acute health effects, but no fatalities] as per *America Industrial Hygiene Association 1990*.

If however the effects exceed the following criteria the consequences are significant (1% or more chance of fatalities) and the installation is a major hazard installation.

- Thermal radiation from fires: 12.5 kW / m^2 for 1 minute > 1 % fatalities [Ref 4], 5 seconds to pain, ignites normal clothing in 60 seconds [Ref 5].

- Blast overpressure from explosions: 14 kPa, collapse of walls and structures [UK HSE required separation distance between developments].

- Toxic gas dose: Equivalent of ERPG 3 concentration for 1 hour and/or < 1% fatalities if using a probit equation for a typical healthy population.

In the range between the above insignificant and catastrophic levels, the MHI classification depends on the particular circumstances prevailing on the site and the characteristics of its surroundings population.

3.3 RISK ASSESSMENT PROCESS

I*SHE*CON is an Approved Inspection Authority by the Department of Labour for the risk assessment of flammable, explosive and toxic substances (Number MHI-001). This is dependent on I*SHE*CON's quality management system for an inspection body being accredited against ISO/IEC 17020 by SANAS (Number MHI-008). (See certificates below).

This study has been carried out in accordance with 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. The risk assessment has been approved by a signatory listed on the SANAS certificate.

I*SHE*CON uses a software package for quantitative risk assessment, PHAST RISK, under license from DNV in the UK (www.dnv.com). This study has been done on Version 6.7.

Republic of South Africa

Department of Labour

Certificate

This is to certify that

ISHECON CC

Has been approved as an

APPROVED INSPECTION AUTHORITY

Type A; Explosive chemicals, Gases, Flammable Gases, Non-Flammable, Non toxic gases (asphyxiants), Toxic gases, Flammable liquids, Flammable solids, Substances liable to spontaneous combustion, Substances that on contact with water release flammable gasses, Oxidizing substances and organic peroxides, Toxic liquids and Solids.

In terms of the Occupational Health and Safety Act, 1993, read with the Major Hazard Installation Regulations 5(5) (a) regarding risk assessments

....
Chief Inspector

Valid From: 13 June 2013 **Expires: 12 June 2017**

MHI 0001
....
Certificate Number

ISHECON
CHEMICAL PROCESS SAFETY ENGINEERS

sanas Inspection Body
MHI008

sanas
South African National
Accreditation System

CERTIFICATE OF ACCREDITATION

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

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

Facility 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 schedule of accreditation, Annexure "A", bearing the above accreditation number for

THE ASSESSMENT OF RISK ON MAJOR HAZARD INSTALLATIONS

The facility is accredited in accordance with the recognised International Standard

ISO/IEC 17020:1998

The accreditation demonstrates technical competency for a defined scope and the operation of a quality 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 R Josias
Chief Executive Officer

Effective Date: 13 June 2013
Certificate Expires: 12 June 2017

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 Labour.

ISHECON
CHEMICAL PROCESS SAFETY ENGINEERS

sanas Inspection Body MHI008

ANNEXURE A

SCHEDULE OF ACCREDITATION

Facility Number: MHI0008

TYPE A

Permanent Address: ISHECON CC H4 Pinelands Ardeer Road Modderfontein 1645 Tel: (011) 997-7945 Fax: (011) 608-2000 E-mail: rademeyerd@ishecon.co.za	**Postal Address:** P O Box 320 Modderfontein 1645 Issue No.: 05 Date of Issue: 13 June 2013 Expiry Date: 12 June 2017

Nominated Representative: Mr DJE Rademeyer	**Quality Manager:** Ms DC Mitchell **Technical Manager:** Mr DJE Rademeyer	**Technical Signatories:** Mr DJE Rademeyer Ms DC Mitchell Mr NN Coni

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	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 Risk Analysis in the Process Industries, IChemE 1985 Guidelines for Chemical Process Quantitative Risk Analysis, Second Ed. 2000 Guideline for Quantitative Risk Assessment "Purple Book" CPR 18E, First Ed. 1999 A Guide for the Control of Major Accident Hazard Regulations 1999, UK HSE.

Original Date of Accreditation: 13 June 2005

Page 1 of 1

ISSUED BY THE SOUTH AFRICAN NATIONAL ACCREDITATION SYSTEM

Field Manager

APPENDIX 4

4.2. METEOROLOGY

4.3. DESIGN DETAILS AND PREVENTATIVE AND PROTECTIVE MEASURES

4.2. WIND AND WEATHER INFORMATION

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

DURBAN SOUTH WEATHER DATA 2013	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW		Humidity	Air Temp	Both Surface Temps
NIGHT																				
F1.5	4.1	2.7	1.9	1.3	1.1	0.8	0.8	1.1	1.1	1.9	3.3	2.3	2.1	2.5	6.3	6.3	39.3	79	16	26
D4.5	0.7	1.7	0.9	1.1	0.5	0.3	0.4	0.6	0.8	1.4	1.0	0.7	0.4	0.2	0.0	0.0	10.7	79	16	26
Total	4.8	4.3	2.8	2.3	1.6	1.2	1.3	1.6	1.9	3.2	4.3	2.9	2.5	2.7	6.3	6.4	50.0			
DAY																				
B3	1.6	2.0	1.2	0.9	0.5	0.4	0.6	0.6	0.8	1.6	1.8	1.0	0.9	0.4	0.4	0.8	15.7	65	26	26
D4.5	1.0	2.4	1.3	1.5	0.7	0.5	0.6	0.8	1.2	2.0	1.4	1.0	0.6	0.3	0.0	0.1	15.3	65	26	26
D8	0.4	2.8	1.5	2.0	0.4	0.1	0.1	1.4	3.4	2.5	2.6	1.0	0.2	0.5	0.0	0.0	19.0	65	26	26
Total	3.0	7.2	4.0	4.5	1.6	0.9	1.3	2.9	5.4	6.1	5.9	3.0	1.7	1.2	0.4	0.9	50.0			

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).

4.3. DESIGN DETAILS AND PREVENTATIVE AND PROTECTIVE MEASURES

General preventative and protective measures

-Site emergency plans
-Firefighting facilities will be provided
-Regular maintenance and inspections of pressure vessels as per legislated requirements
-An emergency flare will be available for excess biogas that cannot be used

Biogas facilities

Limited details are available for these facilities at this time. More specific data should be included in this section in the post-construction MHI RA.

APPENDIX 5

5.1 HAZARDOUS MATERIAL PROPERTIES

PHYSICAL AND FLAMMABLE PROPERTIES
HEALTH HAZARDS
TOXICITY
HAZARDOUS INTERACTION MATRIX

5.2 ACCIDENT AND INCIDENT INFORMATION

5.3 FULL LIST OF INCIDENTS CONSIDERED

5.4 TYPICAL CAUSES OF EVENTS

5.5 CONSEQUENCE ANALYSIS

5.7 MSDSs – METHANE

5.9 LIKELIHOOD ANALYSIS

5.10 RISK ESTIMATION

5.11 RISK EVALUATION

5.1 PROPERTIES OF HAZARDOUS MATERIALS

EXPLOSION, FLAMMABILITY AND REACTIVITY HAZARDS

Compound	BP at 1 atm (degC)	Density at 20deg C kg/m3	Vapour Press @ 20 deg C (kPa)	Flash Point (deg C)	Flammable (Y/N)	Explosive limits in air (vol %)	Auto-ignition Temperature (deg C)	Burning Rate mm/min	Reactivity (H/M/L)
Methane	-161	0.55	V High	Vap	Y	5 - 15	540		L

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/Skin Contact Acute	Ingestion / Skin Contact Chronic
Methane	Carbon mon / di - oxide	Drowsiness and asphyxiation	None	Frostbite (if contact with liquid)	None

TOXICITY INFORMATION

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 ***** d (ppm)	ERPG 2 Value (ppm)	ERPG 3 Value (ppm)	PROBIT k1 ~~	PROBIT k2	PROBIT n
Methane	200	None		Asphyxiant		3 000	5 000	20 000	None		

** - 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.

The inhalation Threshold Limit Values (TLVs) are usually used to gauge the health effects. However, they are really only applicable to workers inside the factory. What is relevant for the public in terms of catastrophic major hazardous incidents is the concentration at which health effects become significant. Often the so called Immediately Dangerous to Life and Health limit (IDLH) or ERPG 3 values are used as preliminary estimates of unacceptable concentrations. However, these are only single values for fixed time periods. For short exposures it is necessary to use probit information. Probits are equations that relate the chance of fatal injury to both the concentration of exposure and the duration of the exposure (i.e. the so called “dose”). Probits can readily be converted into a probability of fatalities (i.e. lethality).

ENVIRONMENTAL TOXICITY

Compound	**Aquatic Life ****
Biogas	Not expected to be harmful to aquatic organisms

HAZARDOUS INTERACTION MATRIX

There is no possibility of reactive material interactions on this site.

APPENDIX 5.2

ACCIDENT AND INCIDENT INFORMATION

The accident data below is extracted from Lees [Ref 8] and the IChemE Accident Database version 4 of 1999 [Ref 9]. All accidents involve biogas.

Date	Material	Event	Consequences
1993	Methane	Explosion in underground water pipeline due to ingress of Methane gas	4 dead 5 injured
1996	Methane	Explosion in Methane gas tank at effluent plant due to welding on roof.	3 dead 1 injured
1988	Methane	Methane gas explosion in sewage collection tunnel.	3 dead
1984	Methane	Fire damaged a compressor station.	1 dead
1966	Methane	Pipe rupture, release 300kg Methane. Explosion.	3 dead 83 injured

APPENDIX 5.3
FULL LIST OF INCIDENTS CONSIDERED AND PROCESS DATA

SCENARIO NAME	MAXIMUM INVENTORY (kg)	VOLUME INVENTORY (M^3)	OPERATING PRESSURE (BAR)	TEMP (CELSIUS)	PHASE TO BE RELEASED	DISTANCE TO BREAK (M)	PIPE SIZE (INTERNAL DIAMETER - MM)
1. PRIMARY DIGESTER INTERNAL EXPLOSION	105.29		0.001	360	Vapour		
2. PRIMARY DIGESTER CATASTROPHIC RUPTURE		1000	0.02	37	Vapour		
3. SECONDARY DIGESTER INTERNAL EXPLOSION	94.76		0.001	360	Vapour		
4. SECONDARY DIGESTER CATASTROPHIC RUPTURE		900	0.02	37	Vapour		
5. BIOGAS GAS HOLDER CATASTROPHIC RUPTURE		4500	0.02	37	Vapour		
6. BIOGAS GAS HOLDER INTERNAL EXPLOSION	94.76		0.02	360	Vapour		
7. BIOGAS TRANSFER LINE FROM DIGESTER TO GAS HOLDER RUPTURE		1000	0.02	37	Vapour	20	150
8. BIOGAS TRANSFER LINE TO SLUDGE DE-WATERING BUILDING RUPTURE		4500	0.02	37	Vapour	20	150
9. DRYING ROOM INTERNAL EXPLOSION	15.44		0.001	360	Vapour		
A. ACCUMULATION OF METHANE FUMES CONFINED EXPLOSION	0.76		0.001	360	Vapour		
B. TOXIC RELEASE H2S - WORST CASE		4500	0.02	37	Vapour		

There are other hazards that are typically considered during a design risk assessment of a new chemical installation, such as pollution, violent release of energy, noise, aesthetics etc. For the purposes of the assessment of major hazards, the focus of the legislation is on the instantaneous detrimental effects. The hazards of noise (low level, not explosions) are not immediate and therefore do not form part of the MHI hazards (note these are addressed in other assessments).

In a similar vein, chronic exposure to chemicals is a long term hazard. It is not a Major Hazard Installation issue, and is rather covered under the Hazardous Substances Regulations and occupational health risk assessments. The hazards associated with the violent release of energy (kinetic or potential) were also not considered (e.g. over pressure burst of air receiver or collapse of structures etc.). Pollution should be considered under the Environmental Management Plan for the installation.

5.4 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 escapes facilities on site.

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.

5.5 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 PHAST RISK (version 6.7). 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. Using the wind weather information presented in APPENDIX 4 (also see description in Section 4) the following two broad weather categories were chosen due to their being the dominant conditions; F1.5 (stable and low wind speed 1.5 m/s typical night time) and D6 / 13 (unstable and moderate to high wind speed, typical day time). These represent both low and high wind speed conditions as well as day and night conditions. Generally the weather condition F with a low wind speed of 1.5 m/s results in the worst case toxic vapour concentrations. The American EPA recommends this scenario must be simulated when doing MHI type risk assessments [Ref. 15]. The UK HSE also uses weather categories similar to this when doing risk assessment verifications [Ref. 16].

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.

FLAMMABLE EFFECTS

The following over pressures are usually considered in a risk assessment, and a pressure of 14 kPa is taken as the MHI fatality threshold for explosions.

TABLE 5.5.3.1 – 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	

Over-pressure (kPa)	Injuries / Fatalities	Structural Damage	Other
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 5.5.3.2 – Levels of Damage at Key Fire Radiation Levels

Radiation Intensity kW / m^2	Exposure Limit (time)	Consequence
75	5 secs	100% lethal
37.5	1 min	100 % lethal, will damage process equipment and structures
15	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 $37.5kW/m^2$ 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 $37.5kW/m^2$ radiation circles being fatally burned within a minute. Outside of the $12.5kW/m^2$ radiation level there are less than 1% fatalities. A level of $4kW/m^2$ is taken as the MHI fatality threshold for huge fires close to open public areas where shelter or escape is unlikely and a level of $12.5kW/m^2$ is taken as the threshold for small fires or where there are buildings and structures that provide some shielding between the public and the source of the fire.

TOXIC EFFECTS

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.

MSDS - Methane

METHANE

MTH

Common Synonyms	Gas	Colorless	Marsh odor
Marsh gas Natural gas	Liquid floats and boils on water. Flammable visible vapor cloud is produced		

Stop discharge if possible. Keep people away.
Shut off ignition sources and call fire department.
Stay upwind and use water spray to "knock down" vapor.
Evacuate area in case of large discharge.
Avoid contact with liquid and vapor.
Notify local health and pollution control agencies.

Fire	FLAMMABLE. Flashback along vapor trail may occur. May explode if ignited in an enclosed area. Stop discharge if possible. Cool exposed containers and protect men effecting shutoff with water. Let fire burn.
Exposure	CALL FOR MEDICAL AID. **VAPOR** Not irritating to eyes, nose or throat. If inhaled, will cause dizziness, difficult breathing, and loss of consciousness. Move to fresh air. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen. **LIQUID** Will cause frostbite. Flush affected areas with plenty of water. DO NOT RUB AFFECTED AREAS.
Water Pollution	Not harmful to aquatic life.

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook)

Issue warning-high flammability
Restrict access
Evacuate area

2. LABEL

2.1 **Category:** Flammable gas
2.2 **Class:** 2

3. CHEMICAL DESIGNATIONS

3.1 **CG Compatibility Class:** Paraffin
3.2 **Formula:** CH_4
3.3 **IMO/UN Designation:** 2.0/1971
3.4 **DOT ID No.:** 1971
3.5 **CAS Registry No.:** 74-82-8

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquefied gas
4.2 **Color:** Colorless
4.3 **Odor:** Mild, sweet

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Self-contained breathing apparatus for high concentrations; protective clothing if exposed to liquid.
5.2 **Symptoms Following Exposure:** High concentrations may cause asphyxiation. No systemic effects, even at 5% concentration in air.
5.3 **Treatment of Exposure:** Remove to fresh air. Support respiration.
5.4 **Threshold Limit Value:** Not pertinent (methane is an asphyxiant, and limiting factor is available oxygen)
5.5 **Short Term Inhalation Limits:** Data not available
5.6 **Toxicity by Ingestion:** Not pertinent
5.7 **Late Toxicity:** None
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors are nonirritating to the eyes and throat.
5.9 **Liquid or Solid Irritant Characteristics:** No appreciable hazard. Practically harmless to the skin, because it evaporates quickly, but may cause some frostbite.
5.10 **Odor Threshold:** 200 ppm
5.11 **IDLH Value:** Data not available

6. FIRE HAZARDS

6.1 **Flash Point:** Flammable gas
6.2 **Flammable Limits in Air:** 5.0%-15.0%
6.3 **Fire Extinguishing Agents:** Stop flow of gas
6.4 **Fire Extinguishing Agents Not to be Used:** Water
6.5 **Special Hazards of Combustion Products:** None
6.6 **Behavior in Fire:** Not pertinent
6.7 **Ignition Temperature:** 1004°F
6.8 **Electrical Hazard:** Class I, Group D
6.9 **Burning Rate:** 12.5 mm/min
6.10 **Adiabatic Flame Temperature:** 2008 (Est.)
6.11 **Stoichiometric Air to Fuel Ratio:** 17.16 (Est.)
6.12 **Flame Temperature:** Data not available

7. CHEMICAL REACTIVITY

7.1 **Reactivity With Water:** No reaction
7.2 **Reactivity with Common Materials:** No reaction
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent
7.7 **Molar Ratio (Reactant to Product):** Data not available
7.8 **Reactivity Group:** 31

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** None
8.2 **Waterfowl Toxicity:** None
8.3 **Biological Oxygen Demand (BOD):** None
8.4 **Food Chain Concentration Potential:** None

9. SHIPPING INFORMATION

9.1 **Grades of Purity:** Research grade; pure grade
9.2 **Storage Temperature:** -260°F
9.3 **Inert Atmosphere:** No requirement
9.4 **Venting:** Safety relief

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-B-C-D-E-F-G

11. HAZARD CLASSIFICATIONS

11.1 **Code of Federal Regulations:** Flammable gas
11.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	4
Health	
Vapor Irritant	0
Liquid or Solid Irritant	0
Poisons	[illegible]
Water Pollution	
Human Toxicity	[illegible]
Aquatic Toxicity	[illegible]
Aesthetic Effect	[illegible]
Reactivity	
Other Chemicals	0
Water	0
Self Reaction	0

11.3 **NFPA Hazard Classification:**

Category	Classification
Health Hazard (Blue)	1
Flammability (Red)	4
Reactivity (Yellow)	0

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 **Physical State at 15°C and 1 atm:** Gas
12.2 **Molecular Weight:** 16.04
12.3 **Boiling Point at 1 atm:** −258.7°F = −161.5°C = 111.7°K
12.4 **Freezing Point:** −296.5°F = −182.5°C = 90.7°K
12.5 **Critical Temperature:** −116.5°F = −82.5°C = 190.7°K
12.6 **Critical Pressure:** 668 psia = 45.44 atm = 4.60 MN/m²
12.7 **Specific Gravity:** 0.422 at −160°C (liquid)
12.8 **Liquid Surface Tension:** 14 dynes/cm = 0.014 N/m at −161°C
12.9 **Liquid Water Interfacial Tension:** (est.) 50 dynes/cm = 0.050 N/m at −161°C
12.10 **Vapor (Gas) Specific Gravity:** 0.55 1.0
12.11 **Ratio of Specific Heats of Vapor (Gas):** 1.306
12.12 **Latent Heat of Vaporization:** 219.4 Btu/lb = 121.9 cal/g = 5.100 X 10^5 J/kg
12.13 **Heat of Combustion:** −21,517 Btu/lb = −11,954 cal/g = −500.2 X 10^5 J/kg
12.14 **Heat of Decomposition:** Not pertinent
12.15 **Heat of Solution:** Not pertinent
12.16 **Heat of Polymerization:** Not pertinent
12.25 **Heat of Fusion:** 13.96 cal/g
12.26 **Limiting Value:** Data not available
12.27 **Reid Vapor Pressure:** Very high

NOTES

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5.9 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 tanks 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.

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 - arm leak	1 E-5 5 E-7 4 E-6 /hour 4 E-5 /hour 3 E-8 /hour 3 E-7 /hour

EQUIPMENT	FAILURE	FREQUENCY Failures/year
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

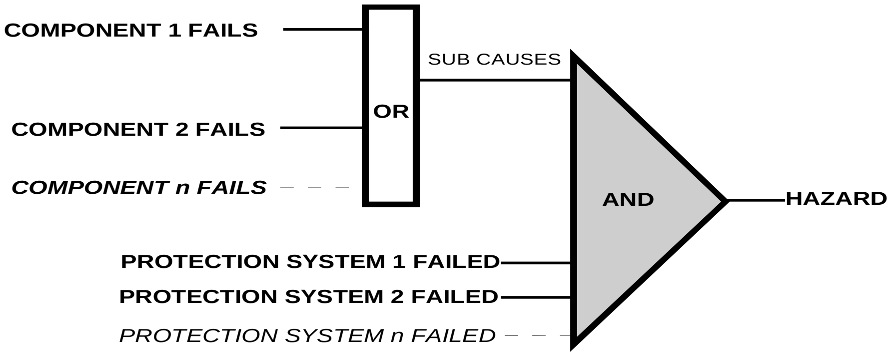
Source	Person	Task Level	Failure Rate Prob of Error
ICI	Operator	Simplest	$1 * 10^{-4}$
		Routine	$1 * 10^{-3}$
		Must take care, e.g. a checklist is needed	$1 * 10^{-2}$
		Non routine	$1 * 10^{-1}$
		Checking another operator	$1 * 10^{-1}$
	Supervisor	Checking an operator	$1 * 10^{-2}$
Du Pont	Operator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

3. 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 must 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.

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).

5.10 RISK CALCULATION

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.

Table 5.10.1 – Population data

Time ↓	Population area →	SWWTW	Residential N	Residential S		
Day	People	500	7220	1875		
	Population density (persons / m^2)	0.003	0.04	0.04		
	Fraction indoors	0.5	0.93	0.93		
Night	People	50	7292	2062		
	Population density (persons / m^2)	0.0003	0.05	0.05		
	Fraction indoors	0.99	0.99	0.99		

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

.

5.11 RISK ASSESSMENT CRITERIA

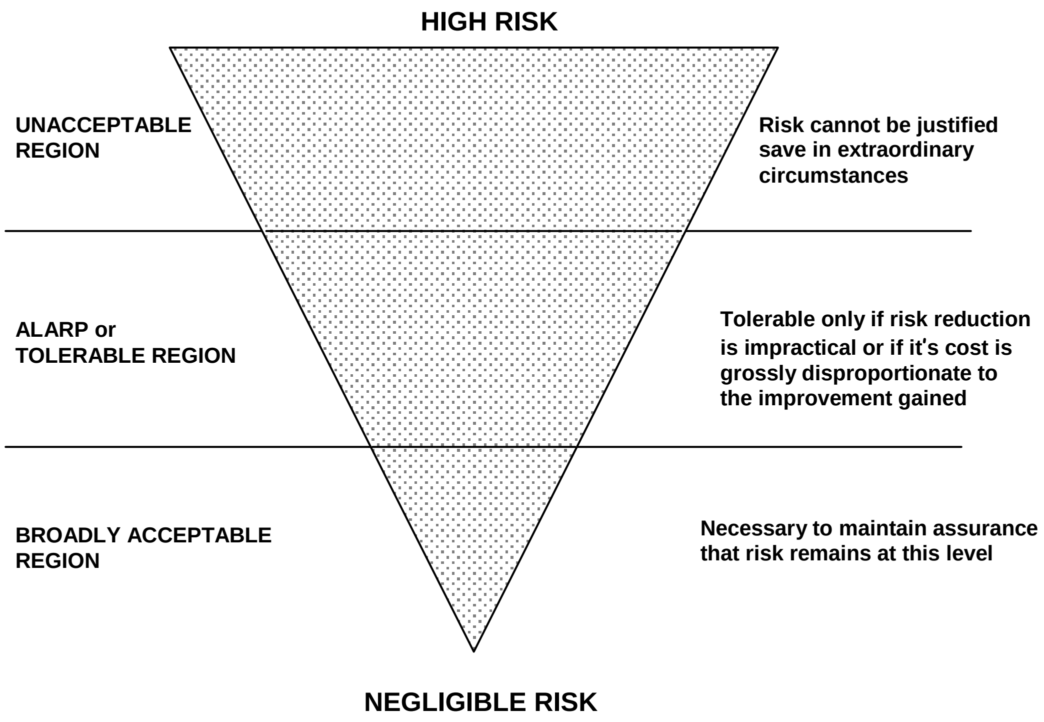
INDIVIDUAL RISK

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 risks. 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 must 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.

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APPENDIX 7

EMERGENCY PLAN

EMERGENCY PROCEDURE EVALUATION CHECKLIST

Emergency Procedures Checklist

The following checklist can be used to guide improvements to the emergency plan for an MHI:

No.	Aspect	Essential emergency elements	Review Evaluation
1.1	Administration	The plan readily available on site for all persons to use when needed (i.e. it should not only be a document on the computer system, there should be summary copies at key locations)	
1.2		The plan, or at least the parts readily available for use, should be simple and concise.	
1.3		The plan should be part of a management system which include means to control the document, ensure revision and updating every 3 years, require witnessing, inclusion of the relevant authorise in reviewing the plan etc.	
1.4		All personnel, visitors, contractors etc. should be trained in the relevant aspects of the emergency plan.	
1.5		Commitment to annual emergency drills	
1.6		The plan should indicate the need to inform the relevant authorities of every occurrence, which has brought the MHI aspects of the plan into action, of actual MHI incidents as well as of near misses.	
1.7		Commitment to communicate all necessary emergency planning information to potentially affected neighbours.	
1.8		Emergency plan signed by Chief executive Officer	
2.1	Contents – roles and responsibilities	The procedures should address all different groups of persons on site e.g. persons who discovers the emergency situation, visitors, staff, first response team, emergency coordinator etc.	
2.2		All personnel should be able to easily determine which group of people they fit into. An organogram is particularly useful.	

No.	Aspect	Essential emergency elements	Review Evaluation
2.3		The actions of the person discovering the emergency situation need to be clearly spelled out.	
2.4		The person who has over all responsibly during an emergency clearly designated e.g. the emergency controller, his/her name and normal job title.	
2.5		Contact names and numbers for key role players should be clearly indicated.	
3.1	Contents – raising the alarm and evacuation	There should be a means of raising the alarm	
3.2		Clear indication who is responsible for raising the alarm (or the various levels of alarm if there is more than one) and the method of doing so.	
3.3		The procedures must clearly describe what actions all personnel are to take in the event that the alarm is raised. If specific groups are to take different actions this must be clear.	
3.4		Procedures for testing the alarm must be indicated.	
3.5		The circumstances under which evacuations are undertaken must be clear.	
3.6		The details of muster/assembly points should be available in the procedures. A map showing the location should be included.	
3.7		The responsibilities of the different persons at the muster points must be clearly defined.	
3.8		Depending on the site and the nature of the risks, there may need to be an indication that the nature of the emergency may require changes in the location of assembly points or actions to be taken once there.	
4.1	Contents – type of emergencies	The plan should cover the major risks assessed i.e. fire, explosion and toxic releases.	

No.	Aspect	Essential emergency elements	Review Evaluation
4.2		The plan must be easy to interpret, i.e. the sections dealing with fire, explosions and toxic gas events must be clearly identifiable on the first or second page and the written layout of the plan should be logical and systematic.	
4.3		Ideally the plan should differentiate between potential fire and explosion situations as well as the situation after an initial fire or explosion.	
4.4		The plan must indicate the location of emergency equipment such as BA sets, foam supplies etc.	
4.5		Persons responsible for ensuring the maintenance of such equipment must be clear.	
4.6		The actions of First Response Teams or emergency controllers may need to be specified in more details, e.g. go to assembly point, don suitable PPE, approach the location of the emergency, isolate releases, activates firefighting systems etc.	
4.7		The location of the designated emergency control centre should be indicated.	
4.8		The facilities to be available at this location and the persons responsible for maintenance thereof must be indicated.	
5.1	Contents – contact with outside	There must be an indication of who is responsible for notifying the external emergency services as well as which services must be contacted under what circumstances.	
5.2		There must be an indication of which external neighbouring facilities need to be notified and who is responsible for this.	
5.3		Contact details for external services and neighbouring facilities must be in the procedures and readily availed to the responsible persons.	

No.	Aspect	Essential emergency elements	Review Evaluation
5.4		There must be a clear indication of what will be communicated to the emergency services as well as to neighbours as per a pre-agreed plan of action.	
5.5		The manner in which roles and responsibilities changes once external emergency services are on site needs to be clear.	
5.6		Access to the site / area during an emergency should be controlled and the means of achieving this must be described.	
5.7		If a specific off-site emergency plan exists then this should be referred to by name/number.	
6.0	Other		

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APPENDIX 8

ORGANIZATION PROCEDURE EVALUATION CHECKLISTS

Organisational Measures Checklist

Measures in the organisation to reduce the major risks can be evaluated as per the table below. This checklist can be used to guide improvement to the management systems on site.

No.	Aspect	Essential elements	Review Evaluation
1.1	Management Leadership	Management has a clear understanding of the major hazards associated with the installation and the implications thereof and the means to prevent escalation of single failures into catastrophic events	
1.2		Clear Management commitment to reducing potential major hazards	
1.3		Safety Management System (both occupational safety and process safety systems) implemented on site that includes a focus on Major Hazards (i.e. process safety aspects)	
1.4		Management system accredited (e.g. OHSAS 18000)	
1.5		Major hazard process safety policies in place	
1.6		Major hazard process safety performance measured and monitored and goals set for continual improvement	
1.7		Clear commitment to providing and maintaining adequate and competent resources to deal with major hazard process safety aspects	
1.8		Regular audits and management reviews	
1.9		Principles of inherent safety considered in the design	
2.1	Safety Documentation	Facility has a complete and up to date set of process and design drawings as well as operating procedures	
2.2		Facility has a complete set of MSDSs for all materials on site	
2.3		Pressure vessels registered	
2.4		Pressurised systems e.g. piping registered	

No.	Aspect	Essential elements	Review Evaluation
2.5		Relief valve register	
2.6		Critical machines e.g. pumps, compressors, fans on a register	
2.7		Trips and interlocks logged on a register	
2.8		Permit to work clearance system	
2.9		Specific procedures for control of contractors	
2.10		Specific lock-out and tagging procedures	
2.11		Change / Modification control procedure	
2.12		Management of change procedure includes specific instructions for review of major process safety hazards	
2.13		Flame and explosion proof electrical equipment register	
3.1	Integrity assurance	Scheduled inspection and testing of pressure vessels	
3.2		Schedule testing of pressure relief valves	
3.3		Scheduled inspection of atmospheric storage tanks	
3.4		Pressurised systems e.g. piping inspected	
3.5		Integrity of concrete and steel structures monitored	
3.6		Critical machines inspected	
3.7		Loading hoses and arms inspected and tested	
3.8		Cathodic protection tested	
4.1	Instrumented protection functionality	Trips interlocks and alarms tested regularly	
4.2		System in place to control trip and interlock defeats or overrides	
4.3		Emergency shutdown systems checked	
5.1	Mechanical protective systems	Relief valves tested	
5.2		Vacuum and pressure relief devices on tanks tested	
5.3		Non return valves checked and overhauled	

No.	Aspect	Essential elements	Review Evaluation
5.4		Vents on tanks and vessels checked	
6.1	Electrical protective systems	Flame and explosion proof electrical equipment inspected and tested	
6.2		Earthing on tanks and equipment checked for continuity	
6.3		Emergency electric power generation regularly checked	
7.1	Process protective system	Inert gas blankets checked and maintained	
8.1	Operator reliability	Operational training carried out	
8.2		Operator assessed competent	
8.3		Refresher training carried out	
8.4		Accident recall and review sessions instituted	
8.5		All equipment identified and labelled	
8.6		Major hazard awareness training program	
9.1	Fire protection and prevention	Fire water availability monitored e.g. pressure	
9.2		Foam inventory and quality monitored	
9.3		Emergency diesel fire water pump regularly tested	
9.4		Fire detection and alarms checked and tested	
9.5		Fire extinguishers tested regularly	
10.		Other	