PROJECT DONE ON BEHALF OF
SAVANNAH ENVIROMENTAL (PTY) LTD

RISK ASSESSMENT FOR THE PROPOSED ANKERLIG CCGT CONVERSION PROJECT AT ATLANTIS, WESTERN CAPE

Report No.: R/08/SAV-01 Rev 0

AUGUST 2008

M P Oberholzer

RISCOM

P O Box 2541, Cresta, 2118
Tel: +27 (0) 82 457 3258
Fax: : 086 624 9423
e-mail: mike@riscom.co.za

GOVERNMENT APPROVED INSPECTION AUTHORITY No MHI 005

SANAS ACCREDITED Inspection Body

ACCREDITED INSPECTION BODY No MHI 013

DOCUMENT CHANGE HISTORY			
PAGE/LINE	**CHANGE**	**DATE**	**REV**
	Initial Release	Aug 08	0

ACKNOWLEDGEMENTS

The author would like to express their sincere appreciation for the assistance in supplying all the necessary information from Jo-Anne Thomas of Savannah Environmental (Pty) Ltd and Nico Gewers of Eskom.

RISCOM (PTY) LTD

Riscom (Pty) Limited is a consulting company specialising in process safety. Further to this, Riscom is an approved inspection authority for conducting Major Hazard Installation (MHI) risk assessments in accordance to the OHS Act 85 of 1993 and the Major Hazard Installation Regulations (July 2001). In order to maintain our status of an approved inspection authority, Riscom is accredited by the South African National Accreditation System (SANAS) in accordance with IEC/ISO 17020. The accreditation consists of a number of elements including technical competence and 3rd party independence. Thus Riscom has successfully demonstrated competency and independence to an internationally recognised accreditation body. Verification of Riscom's accreditation can be found on the SANAS website.

Riscom's independence is demonstrated by the following:

- Riscom does not sell or repair equipment that can be used in the process industry;
- Riscom does not have any shareholding in processing companies nor companies performing EIA functions;
- Riscom does not design equipment or processes;
- Riscom is not involved in any activity that may conflict or alter the outcome of this study.

Mike Oberholzer is a Professional Engineer and holds a BSc (Chemical Engineering). He is an approved signatory for MHI risk assessments, thus meeting the competency requirements of SANAS for assessments of hazardous materials covering, fire, explosions and toxic releases.

INDEMNITY

Riscom shall not be liable for any loss or damage (actual or consequential), which may be suffered by the client or any other person arising out of any cause whatsoever relating to this study.

ASSESSMENT FOR THE PROPOSED ANKERLIG CCGT CONVERSION PROJECT AT ATLANTIS, WESTERN CAPE

EXECUTIVE SUMMARY

INTRODUCTION

The existing Ankerlig OCGT Power Station consists of nine OCGT units (i.e. four existing OCGT units, plus an additional five OCGT units, currently under construction) resulting in a total nominal capacity of 1 350 MW for the power station. The conversion of the power plant to CCGT units consists of recovering waste heat from each turbine to drive a steam turbine.

The CCGT project also consists of increasing the storage of diesel on site and thus Riscom (Pty) Ltd was commissioned to conduct a fuel oil risk assessment study to determine the extent of impacts from accidental fires and explosions.

1.1 Terms of Reference

This study was limited to the hazards posed by the fuel oil storage and did not cover mechanical failures such as turbines.

The main aim of the investigation was to determine the extent of impact from accidental fires with regards to the proposed CCGT conversion and storage tanks to the Ankerlig Power Station at Atlantis, Western Cape.

This study does not replace a quantitative risk assessment that will have to be conducted after the detailed design stage as required by the MHI Regulations (July 2001). See Appendix A for brief overview of the requirements of the MHI Regulations.

1. Compare safety distances as given in SANS codes
2. To develop accidental spill and fire scenarios for the proposed offloading and storage;
3. Using generic failure rate data (tanks, pumps, valves, flanges, pipe work, gantry, couplings, etc.), determine the probability of each accident scenario.

4. For each incident developed in Step 2, determine the consequences (thermal radiation, domino effect, etc.).
5. Calculate Maximum Individual Risk (MIR) values taking into account all accidents, under worst meteorological conditions and lethality.

1.2 Purpose and Main Activities

The main activity of the power plant is the generation of electricity that will be incorporated into the national electrical grid.

1.3 Main Hazard Due To Substance and Process

The main hazard of the facility would be thermal radiation from large pool fires and explosions from the fuels and flammable gases stored on site.

2 ENVIRONMENT

The Ankerlig OCGT Power Station is located off Dassenburg Road in the Atlantis Industria (remainder of farm 1183) as shown below in Figure 2-1. The CCGT conversion and proposed new storage tanks are located on the northern section of the sate

The land use surrounding the Ankerlig Power Station is industrial within the Atlantis Industrial township. To the west of Ankerlig Power Station is agricultural ground.

3 PROCESS AND STORAGE TANK FACILITY

3.1 Ankerlig Power Station

3.1.1 OCGT Plant

The OCGT plant was the first project on site and consists of 4 diesel operated Open Cycle Gas Turbines (OCGT), fuel storage, workshops and offices. The diesel is delivered to site in road tankers and offloaded at a dedicated bay that can accommodate the simultaneous offloading of 4 road tanker with the use of flexible hosing.

From the offloading bay, the diesel is pumped to the first diesel tank as primary storage. From here it is filtered to remove particulate matter and placed into the clean diesel tank from where it is pumped to the turbines for the generation of power

The tanker offloading bay is slightly recessed below grade and sloped to a drainage point. Thus all spillages are contained within the area and are drained to the Dirty Dam located at the southern portion of the site outside of the security area. The Dirty Dam is fully fenced with restricted access to authorised personnel.

The diesel tanks, each of 2700 m^3 nominal capacity, are located at the southern boundary of the site and are fully bunded to contain the volume of the tanks and an additional volume to contain fire water.

The building containing the pumps and filtration is located adjacent to the diesel tanks and is recessed below ground with the floor sloping towards the drainage point. All spilt hydrocarbons within the area report to the Dirty Dam where the hydrocarbons are separated from water.

Propane is used to initiate the combustion of the diesel and is thus used at start-up only. Two propane tanks of 6.5 m^3 each are located west of the Control room. After one tank has been emptied, the supply to the turbine is switched to the full standby tank and the empty tank filled. Propane is received approximately once per month in 20 m^3 road tankers and offloaded adjacent to the storage tanks.

Lube oil is used for the turbine operation and located within a short proximity of the turbines. All spilt lube oil would report to the Dirty Dam.

An emergency diesel generator is located on site with a 5 m^3 diesel storage tank with secondary containment.

3.1.2 Gas–1 Plant

The Gas-1 Plant (currently under construction) is similar in design to the OCGT plant and would operate independently of the OCGT plant. This plant will consist of 5 turbines, 4 x 6.5 m^3 propane tanks and 2 x 2700 m^3 and 1 x 5400m^3 diesel tanks and a road offloading bay capable of receiving 5 road tankers simultaneously.

The Gas-1 plant would have a separate Dirty Dam where all spillages from offloading, filtration and other potential hydrocarbon spillages would be collected and separated.

3.1.3 CCGT Conversion

The CCGT conversion project involves the inclusion of 8 x 5400 m^3 diesel storage tanks. For this project it was assumed that diesel would be delivered to site in 72 m^3 rail tankers with 10 offloading bays and no spill protection.

4 HAZARD IDENTIFICATION

The first step in any risk assessment is to identify all hazards. The merits of including the hazard for further investigation are subsequently determined by its significance, normally using a cut-off or threshold quantity.

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

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

- Chemical identities;
- Location of facilities that use, produce, process, transport or store hazardous materials;
- The type and design of containers, vessels or pipelines;
- The quantity of material that could be involved in an airborne release; and,
- The nature of the hazard (e.g. airborne toxic vapours or mists, fire, explosion, large quantities stored or processed handling conditions) most likely to accompany hazardous materials spills or releases.

Diesel was found to be a combustible liquid while propane was found to be a flammable gas at room temperature.

5 CONCLUSIONS

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

The risk assessment was done on the assumption that the site will be maintained to an acceptable level and that all-statutory regulations will be applied. It was also assumed that the detailed engineering designs will be performed by competent people and that the plant requirements will be correctly specified for the intended duty.

A number of incident scenarios were considered and the following conclusions were reached.

5.1 Pool Fires

Large bund fires and pool fires from spillages from road and rail offloading operations were calculated for the Ankerlig Power Station and the proposed CCGT conversion. The study concluded that Ankerlig Power station and the CCGT conversion could have impacts a short distance beyond the site boundary.

The risks from pool and bund fires of $1x10^{-6}$ fatalities per person, which is generally considered as tolerable, extended beyond the site's boundary and in some instances were excessive.

As the $1x10^{-4}$ fatalities per person per year lies a short distance over the boundary there is possibility to reduce risks to acceptable levels with engineering and administrative controls.

5.2 Jet fires

Jet fires from a release of pressurised propane would form a maximum flame length of 20.4 m. This flame would not extend beyond the site's boundary but could injure people and damage equipment within the flame.

5.3 Explosions

As a result of additional structures for the CCGT conversion, a large lease of propane could result in a partial confined explosion that could extend beyond the site's boundary. However the risks for offsite fatalities are considered acceptable.

5.4 Major Hazardous Installation

This investigation concluded that the CCGT conversion would have risk excessive of $1x10^{-6}$ fatalities per person per year at the site boundary and would classify the facility as a Major Hazardous Installation. While there is potential to reduce the impacts and risks, a quantitative risk assessment would be required in terms of the Major Hazardous Installation (MHI) Regulations (July 2001) prior to project construction. The risk assessment must be done with final designs and layouts. Exemption from completing a MHI risk assessment can not be done at this stage as designs are preliminary and subject to change.

6 RECOMMENDATIONS

As a result of the risk assessment study conducted for the fuel storage facility for the proposed OCGT conversion, the following are recommendations:

6.1 Major Hazardous Installation Risk Assessment

As off-site consequences are possible, a quantitative risk assessment would be required in terms of the Major Hazardous Installation (MHI) Regulations (July 2001) prior to project construction. The risk assessment must be done by an Approved Inspection Authority, as recognised by the Department of Labour, with final designs and layouts.

6.2 Project Approval

Large petrochemical storage facilities have been installed around the world having acceptable risks. While consequences of the fuel storage facility may extend beyond the sites' boundaries, the risk can be engineered to within acceptable risks.

As a result of the risk assessment study conducted for the proposed CCGT conversion project, no fatal flaws were apparent that could prevent the project proceeding. It is thus recommended that the project proceed into the detailed phase of the design with the following provisions:

i. Compliance to all statutory requirements e.g. Vessel Under Pressure Regulations etc.;
ii. Compliance with applicable SANS codes SANS 10087-3, SANS 10108. etc.;
iii. A recognised process hazard analysis (HAZOP, FMEA, etc) should be completed for the proposed plant prior to construction. This is to ensure design and operational hazards have been identified adequate mitigation put in place. It would be preferable if study could be facilitated by an independent party that can not benefit financially from offering services, equipment or instrumentation for the project;
iv. A safety document detailing safety and design features reducing the impacts from fires, explosions and flammable atmospheres must be prepared and issued to the MHI assessment body at the time of the MHI assessment. The built facility can be audited against the safety document to ensure compliance with the EIA Terms of Reference. Codes such as IEC 61511 can be used to achieve these requirements. Eskom and their contractors must demonstrate that sufficient mitigation has been included in the designs to ensure the safety of the surrounding neighbours and the public.
v. Emergency response documentation must be done with input from local authorities; and;
vi. A risk assessment in accordance to the prescribed Major Hazard Installation (MHI) Regulations must be conducted after completion of the final designs and layout, but prior to construction.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

RISK ASSESSMENT FOR THE PROPOSED ANKERLIG CCGT CONVERSION PROJECT AT ATLANTIS, WESTERN CAPE

1 INTRODUCTION

The existing Ankerlig OCGT Power Station consists of nine OCGT units (i.e. four existing OCGT units, plus an additional five OCGT units, currently under construction) resulting in a total nominal capacity of 1 350 MW for the power station. The conversion of the power plant to CCGT units consists of recovering waste heat from each turbine to drive a steam turbine.

The CCGT project also consists of increasing the storage of diesel on site and thus Riscom (Pty) Ltd was commissioned to conduct a fuel oil risk assessment study to determine the extent of impacts from accidental fires and explosions.

1.1 Legislation

Concern about public health and safety has led to the regulation of the handling, storage and use of industrial chemicals. On 16 January 1998, the Major Hazard Installation Regulations was promulgated under the Occupational Health and Safety Act 1993 (Act No 85 of 1993), with a further amendment on 30 July 2001. The provisions of the regulations apply to installations, which have on their premises a quantity of a substance, which can pose a significant risk to the health and safety of employees and the public.

The regulations (Appendix A) essentially consists of six parts, namely

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

This report contains information summaries with special focus on quantitative risk assessment and comment on-site emergency plans. The requirements following an incident and the general duties required by the supplier and local government will merely be repeated from the regulations.

1.2 Terms of Reference

This study was limited to the hazards posed by the fuel oil storage and did not cover mechanical failures such as turbines.

The main aim of the investigation was to determine the extent of impact from accidental fires with regards to the proposed CCGT conversion and storage tanks to the Ankerlig Power Station at Atlantis, Western Cape.

This study does not replace a quantitative risk assessment that will have to conducted after the detailed design stage as required by the MHI Regulations (July 2001). See Appendix A gives for brief overview of the requirements of the MHI Regulations.

1. Compare safety distances as given in SANS codes
2. To develop accidental spill and fire scenarios for the proposed offloading and storage;
3. Using generic failure rate data (tanks, pumps, valves, flanges, pipe work, gantry, couplings, etc.), determine the probability of each accident scenario.
4. For each incident developed in Step 2, determine the consequences (thermal radiation, domino effect, etc.).
5. Calculate Maximum Individual Risk (MIR) values taking into account all accidents, under worst meteorological conditions and lethality.

1.3 Purpose and Main Activities

The main activity of the power plant is the generation of electricity that will be incorporated into the national electrical grid.

1.4 Main Hazard Due To Substance and Process

The main hazard of the facility would be thermal radiation from large pool fires and explosions from and flammable gases stored on site.

2 ENVIRONMENT

2.1 General Background

The Ankerlig OCGT Power Station is located off Dassenburg Road in the Atlantis Industria (remainder of farm 1183) as shown below in Figure 2-1. The CCGT conversion and proposed new storage tanks are located on the northern section of the sate

The land use surrounding the Ankerlig Power Station is industrial within the Atlantis Industrial township. To the west of Ankerlig Power Station is agricultural ground.

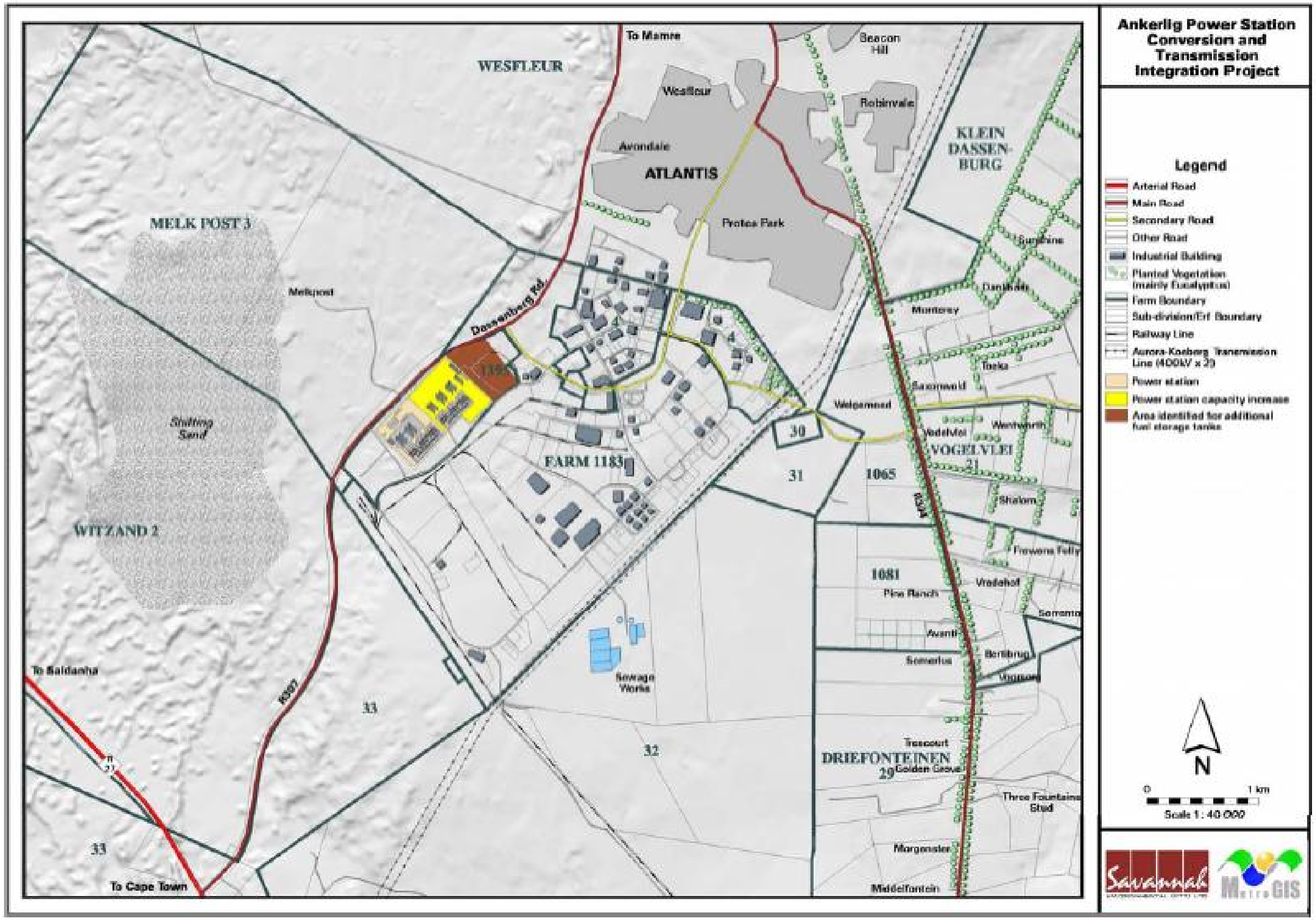


Figure 2-1 Map showing the locality of the Ankerlig Powers Station CCGT conversion and surrounding land use (Courtesy Savannah Environmental)

3 PROCESS AND STORAGE TANK FACILITY

The risk assessment focused on the site and the immediate surroundings. The drawings referenced include:

Drawing No	Title	Rev / Date
Unknown	Ankerlig Power Station Station Layout	Unknown
JEV-LAY-002A	Fuel Unloading Skid Layout	1
JEV-PID-002B	PID of Fuel Unloading Skid & Tanks Typical	1
JEV-PID-003B	PID of Fuel Forwarding Skids Typical	1
RSA804-XG02-MBQ10-250001	Supply of Ignition Gas Ignition Gas Tanks MODUL 03 04 MBQ10 P&I Diagram	A

3.1 Ankerlig Power Station

3.1.1 OCGT Plant

The OCGT plant was the first project on site and consists of 4 diesel operated Open Cycle Gas Turbines (OCGT), fuel storage, workshops and offices. The diesel is delivered to site in road tankers and offloaded at a dedicated bay that can accommodate the simultaneous off loading of 4 road tanker with the use of flexible hosing.

From the offloading bay, the diesel is pumped to the first diesel tank as primary storage. From here it is filtered to remove particulate matter and placed into the clean diesel tank from where it is pumped to the turbines for the generation of power

The tanker offloading bay is slightly recessed below grade and sloped to a drainage point. Thus all spillages are contained within the area and are drained to the Dirty Dam located at the southern portion of the site outside of the security area. The Dirty Dam is fully fenced with restricted access to authorised personnel and

The diesel tanks, each of 2700 m^3 nominal capacity, are located at the southern boundary of the site and are fully bunded to contain the volume of the tanks and an additional volume to contain fire water.

The building containing the pumps and filtration is located adjacent to the diesel tanks and is recessed below ground with the floor sloping towards the drainage point. All spilt hydrocarbons within the area report to the Dirty Dam where the hydrocarbons are separated from water.

Propane is used to initiate the combustion of the diesel and is thus used at start-up only. Two propane tanks of 6.5 m^3 each are located west of the Control Room. After one tank has been emptied, the supply to the turbine is switched to the full standby tank and the empty tank filled. Propane is received approximately once per month in 20 m^3 road tankers and offloaded adjacent to the storage tanks.

Lube oil is used for the turbine operation and located within a short proximity of the turbines. All spilt lube oil would report to the Dirty Dam.

An emergency diesel generator is located on site with a 5 m^3 diesel storage tank with secondary containment.

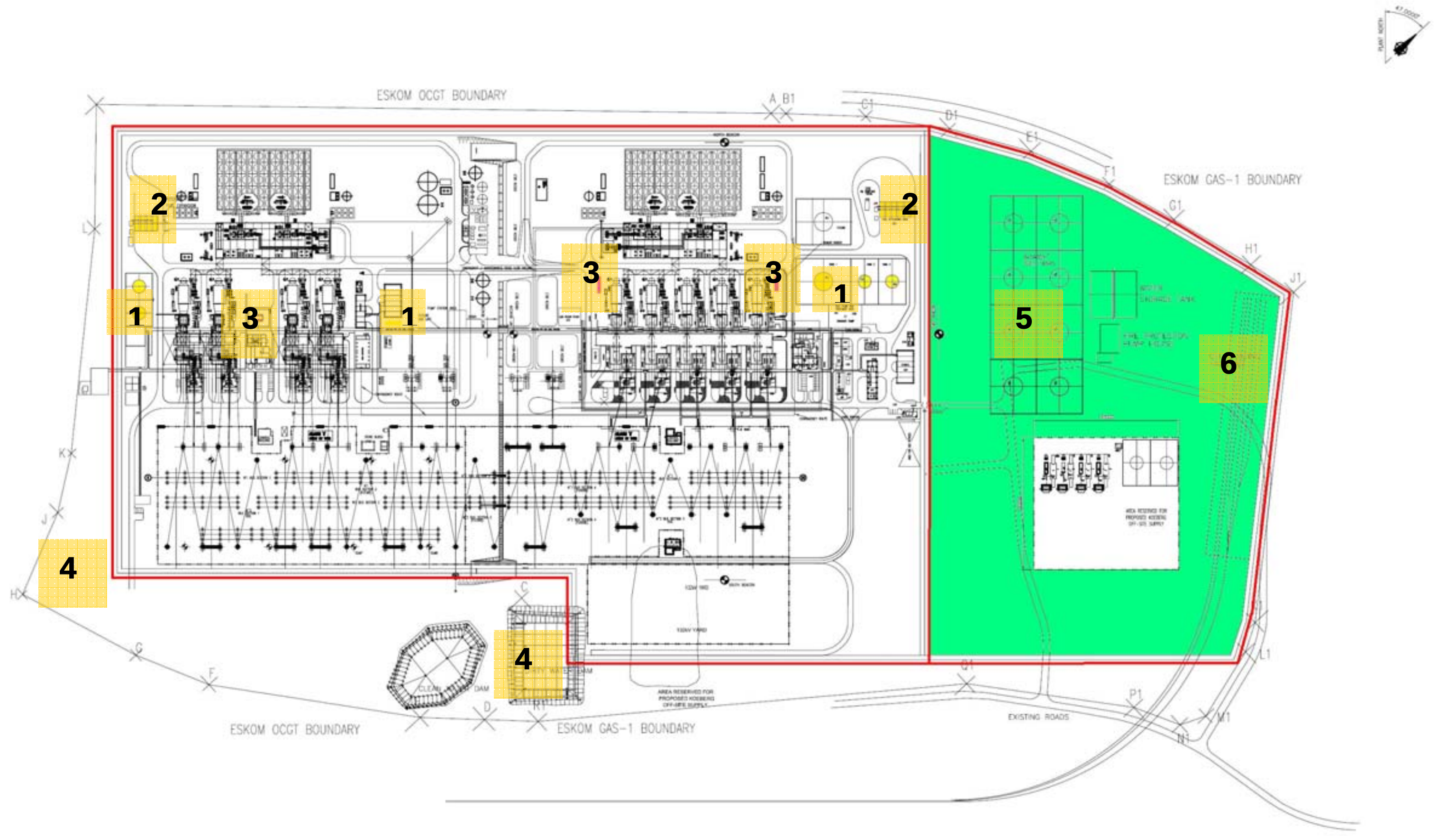
3.1.2 Gas–1 Plant

The Gas-1 Plant (currently under construction) is similar in design to the OCGT plant would operate independently of the OCGT plant. This plant will consist of 5 turbines, 4 x 6.5 m^3 propane tanks and 2 x 2700 m^3 and 1 x 5400m^3 diesel tanks and a road offloading bay capable of receiving 5 road tankers simultaneously.

The Gas-1 plant would have a separate Dirty Dam where all spillages from offloading, filtration and other potential hydrocarbon spillages would be collected and separated.

3.1.3 CCGT Conversion

The CCGT conversion project involves the inclusion of 8 x 5400 m^3 diesel storage tanks. For this project it was assumed that diesel would be delivered to site in 72 m^3 rail tankers with 10 offloading bays and no spill protection.



TAG	DESCRIPTION	TAG	
1	Diesel Storage	2	Road Offloading
3	Propane Storage	4	Dirty Dams
5	CCGT Storage Tanks	6	Proposed Rail Offloading

Figure 3-1 Layout of the proposed CCGT expansion at the Ankerlig Power Station at Atlantis, Western Cape

3.1.4 Plant Layout

As relatively large amounts of flammable material will be stored on site, the layout must be done to protect the safety of employees and the public in accordance with the Occupational Health and Safety Act 85 of 1993 and the requirements of local authorities.

A guideline for the handling and storing of petrochemical and derivative chemicals are available in SANS 10089-1 (formerly SABS 089-1). Part 1: Storage and distribution of petroleum products in above ground bulk installations.

A guideline for the handling, storage, and distribution of liquefied petroleum gas in domestic, commercial and industrial installations is available in SANS 10087-3: (formerly SABS 087-3). Part 3: Liquefied petroleum gas installations involving storage vessels of individual water capacity exceeding 500 ℓ.

Compliance of these codes does not automatically grant immunity from relevant legal requirements, including municipal and other bylaws. However, compliance with this standard is the first step in obtaining approvals for installation of new tank age.

3.1.5 Classification of Flammable products

Flammable products are classified in terms of SANS 1089-1 according to their flash points and boiling points, which ultimately determines the propensity to ignite. Separation distances described in the various codes are dependant on the flammability classification. The classification of material according to flash point as per SANS 10089-1 is shown in Table 3-1.

Table 3-1 Classification of flammable products

Class	Description
0	Liquefied Petroleum Gas
IA	Liquids that have a closed-cup flash point of below 23°C and boiling point below 35°C
IB	Liquids that have a closed-cup flash point of below 23°C and boiling point of 35°C or above
IC	Liquids that have a closed-cup flash point of 23°C or above, but below 38°C
II	Liquids that have a closed-cup flash point of 38°C or above, but below 60.5°C
IIIA	Liquids that have a closed-cup flash point of 60.5°C or above, but below 93°C
IIIB	Liquids that have a closed-cup flash point of 93°C or above

Following the classification of Table 3-1, propane is classified as Class 0, diesel II and lube oil IIIB.

3.2 Tank and Bund Sizing

As per the SANS 10089, the volume of the largest tank must be fully contained. The bund should also contain 40 minutes of fire fighting water to prevent an environmental incident. A bund wall height of over 1.8 m requires special requirements in accordance to the code as it contains additional hazards. It is recommended that the bund wall height be reviewed in light of the code or additional safety measures be introduced.

3.3 Safety Distances

The specified safe distances between tanks, tanks and the public road, and neighbouring property can be found in SANS 10089-1:2003.

The following subsections contain indicative safety distances which are based on the assumed capacities and dimensions of the fuel tanks.

3.3.1 Minimum Distance From Tanks To The Bund Wall

The minimum recommended distance from the tank to the bund walls as indicated in SANS 10089 is 1.5 m.

3.3.2 Minimum Shell-To Shell Safety Distance

The minimum recommended shell-to-shell distance from SANS 10089-1 is one sixth of the sum of the adjacent tank diameter but not less than 1 m.

3.3.3 Minimum Distance From The Bund Wall To The Site Boundary

The distance recommended in SANS 10089-1 provides a gap between the storage facility and the boundaries of properties that can be built on, and is intended to reduce any consequences of catastrophic effects from the storage facility to neighbours and public. The safety distances for various size tanks are given in Table 3-2. Under the current layout the safety distances would meet the code.

The distance to a public road and buildings is indicated below Table 3-2. The specification of the buildings must include sufficient protection of personnel in the event of a fire. The building specifications required to withstand fires must be adequately addressed. Buildings that have limited capabilities to withstand the consequence of fires should be located further away than the distances suggested in Table 3-2.

Table 3-2 Safety distances given in SANS 10089-1 (2003) for low pressure tanks and no protection provided for people.

Tank capacity (m3)	Minimum distance from boundary of a property that is or can be built on, including the far side of a public road. (m)	Minimum distance from the near side of a public road. or from the nearest important building on the same property (m)
Less than 1	3	1.5
1.0 – 2.2	6	1.5
2.201 – 45.0	9	1.5
45.001 – 82.0	12	1.5
82.001 – 200.0	18	3
20.001 – 378.0	30	4.5
378.001 – 1 892.5	50	7.6
1 892.501 – 3 785.0	61	11
3 785.001 – 7 570.0	82	13.7
7 570.001 – 11 355.0	100	17
11 355.001 or more	106	18

3.3.4 Minimum Distance Between Tanks And Filling Point.

Minimum distances between the tanks and offloading should be 15 m. No internal combustion engine should come closer than 15 m from the filling vehicle.

3.3.5 Compliant with SANS Standards

The proposed storage tanks would be compliant SANS 10089-1. It is recommended that the final designs be re-checked for compliance prior to construction

3.4 Summary of Hazardous Materials Stored on the Atlantis OCGT Power Station

3.4.1 OCGT Plant

Figure 3-2 Summary of tank inventories of the current project

TANK No	PRODUCT	TANK TYPE	TANK HEIGHT (m)	TANK DIAMETER (m)	TANK VOLUME (m^3)	LIQUID STORED (Tonnes)	BUND VOLUME (m^3)
1	Diesel	Atmospheric, fixed roof	16.82	14.75	2700	2187	3857
2	Diesel	Atmospheric, fixed roof	16.82	14.75	2700	2187	3857
3	Diesel	Atmospheric, fixed roof			5	4.05	5
3	Propane	Pressure, horizontal			6.5	3.67	N/A
4	Propane	Pressure, horizontal			6.5	3.67	N/A

3.4.2 Gas-1 Plant

Figure 3-3 Summary of tank inventories of the proposed project

TANK No	PRODUCT	TANK TYPE	TANK HEIGHT (m)	TANK DIAMETER (m)	TANK VOLUME (m^3)	LIQUID STORED (Tonnes)	BUND VOLUME (m^3)
1	Diesel	Atmospheric, Fixed roof	16.82	14.75	2700	2187	2930
2	Diesel	Atmospheric, Fixed roof	16.82	14.75	2700	2187	2930
3	Diesel	Atmospheric, Fixed roof	16.8	21	5400	4374	5861
P1	Propane	Horizontal, Pressure			6.5	3.78	N/A
P2	Propane	Horizontal, Pressure			6.5	3.78	N/A
P3	Propane	Horizontal, Pressure			6.5	3.78	N/A
P4	Propane	Horizontal, Pressure			6.5	3.78	N/A
L1	Lube Oil	Atmospheric, Fixed roof			6		N/A

TANK No	PRODUCT	TANK TYPE	TANK HEIGHT (m)	TANK DIAMETER (m)	TANK VOLUME (m^3)	LIQUID STORED (Tonnes)	BUND VOLUME (m^3)
L2	Lube Oil	Atmospheric, Fixed roof			6		N/A
L3	Lube Oil	Atmospheric, Fixed roof			6		N/A

3.4.3 CCGT Conversion

Figure 3-4 Summary of tank inventories of the proposed project

TANK No	PRODUCT	TANK TYPE	TANK HEIGHT (m)	TANK DIAMETER (m)	TANK VOLUME (m^3)	LIQUID STORED (Tonnes)	BUND VOLUME (m^3)
1	Diesel	Atmospheric, Fixed roof	16.8	21	5400	4374	5861
2	Diesel	Atmospheric, Fixed roof	16.8	21	5400	4374	5861
3	Diesel	Atmospheric, Fixed roof	16.8	21	5400	4374	5861
4	Diesel	Atmospheric, Fixed roof	16.8	21	5400	4374	5861
5	Diesel	Atmospheric, Fixed roof	16.8	21	5400	4374	5861
6	Diesel	Atmospheric, Fixed roof	16.8	21	5400	4374	5861
7	Diesel	Atmospheric, Fixed roof	16.8	21	5400	4374	5861
8	Diesel	Atmospheric, Fixed roof	16.8	21	5400	4374	5861

4 HAZARD IDENTIFICATION

The first step in any risk assessment is to identify all hazards. The merits of including the hazard for further investigation are subsequently determined by its significance, normally using a cut-off or threshold quantity.

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

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

- Chemical identities;
- Location of facilities that use, produce, process, transport or store hazardous materials;
- The type and design of containers, vessels or pipelines;
- The quantity of material that could be involved in an airborne release; and,
- The nature of the hazard (e.g. airborne toxic vapours or mists, fire, explosion, large quantities stored or processed handling conditions) most likely to accompany hazardous materials spills or releases.

4.1 Notifiable Substances

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

No notifiable substances will be stored or processed at the proposed expansion of the Ankerlig Power Station.

4.2 Substance Hazards

All components on the plant were assessed for potential hazards according to the criteria discussed below.

4.2.1 Chemical Properties

4.2.1.1 Diesel

Diesel is a hydrocarbon mixture with variable composition. It is a pale yellow liquid with a petroleum odour. Due to the minimum flash point of diesel of 55°C, this material is not considered highly flammable but will readily ignite under suitable conditions.

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

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

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

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

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

4.2.1.2 Propane

Propane is a colourless gas at room temperature with an odour of commercial natural gas. It has a low boiling point of – 41.9°C and is often compressed, transported and sold as a liquid, primarily as a fuel.

Propane is a severe fire and explosion hazard with an invisible vapour that spreads easily and can be set on fire by many sources such as pilot lights, welding equipment, electrical motors, switches, etc. It is heavier than air and can travel along ground for some distance to an ignition source.

Propane is not compatible with strong oxidants and can result in fires and explosions.

Propane is not considered a carcinogenic material. The toxicology and the physical and chemical properties of propane suggest that overexposure is unlikely to aggravate existing medical conditions.

Overexposure to propane may cause dizziness & drowsiness. Effects of a single (acute) overexposure may result in asphyxiation due to lack of oxygen that could be fatal. Self-contained breathing apparatus may be required by rescue workers. Moderate concentrations may cause headache, drowsiness, dizziness, excitation, excess salivation, vomiting, and unconsciousness. Vapour contact with the skin will not cause any harm. However contact with liquid may cause frostbite due to low temperature of the liquid propane.

4.2.1.3 Lube Oil

Lube oil or mineral oil is a transparent colourless oily liquid that is practically tasteless and odourless, even when warmed. Due to the high flash point of lube oil, the material is not considered flammable. Lube oil is not considered toxic.

Saturated aliphatic hydrocarbons, which are contained in lube oil, may be incompatible with strong oxidizing agents like nitric acid. Charring of the hydrocarbon may occur followed by ignition of unreacted hydrocarbon and other nearby combustibles. In other settings, aliphatic saturated hydrocarbons are mostly unreactive. They are not affected by aqueous solutions of acids, alkalis, most oxidizing agents, and most reducing agents. When heated sufficiently or when ignited in the presence of air, oxygen or strong oxidizing agents, they burn exothermically to produce carbon dioxide and water.

4.2.2 Corrosive Liquids

Corrosive liquids considered under this section are those chemicals that have a low or high pH that may burn if they comes into contact with people or they may attack and cause failure of equipment.

Diesel, propane and lube oil are not considered corrosive.

4.2.3 Reactive Chemicals

Reactive chemicals are chemicals that when mixed or exposed to one another react in a way that may cause a fire, explosion or release a toxic component.
Hydrocarbons will react with strong oxidising agents with a fire and explosion hazard. However no toxic, or hazardous material are expected with chemical reactions of the materials stored on site

4.2.4 Flammable materials

Flammable materials are those that can ignite to give a number of possible hazardous effects, depending on the actual material and conditions. These are flash fires, explosion, fireball, jet fire or pool fire.

The flammable and combustible materials on site are listed below. All these components have been analysed for fire risks.

Table 4-1 Flammable and combustible fuels on site

Compound	Typical Flash Point (°C)	Comment
Diesel	~55	Flash points may vary with product specifications
Lube Oil	149	
Propane	Flammable gas	

4.2.5 Toxic materials

Toxic materials of interest to this study are those that could give dispersing vapour clouds upon release into the atmosphere. These could subsequently cause harm through inhalation or absorption through the skin. Typically the hazard posed by a toxic material will depend both on concentration of the material in the air and the exposure duration.

Diesel, lube oil and propane are not considered toxic materials.

4.3 Incident Root Causes

A relatively recent investigation of chemical incidents in the USA for a ten-year period (1987-1996), identified approximately 605 000 unique chemical incidents, with 42% occurring at fixed locations occupied by industrial and commercial businesses, and 43% related to transportation (CBS 1999).

About 29% of these incidents resulted in at least one fatality (1.6%), evacuation of workers and/or the public (0.7%), or property damage (27%). The balance of the incidents held the potential for undesired consequences. These incidents were most frequently reported for the chemical manufacturing and fuel companies, with gasoline, being the substance most often involved in incidents (21.2%).

Unfortunately, the actual cause of an incident was never recorded in the databases used in the analyses; only the presumed initiating event was identified. The incidents were grouped into "*Mechanical Failure*", "*Human Factor*", "*Natural Phenomenon*", "*Other*" and a large group constituting those for which no data were available ("*Unknown*").

Figure 4-1 summarises the number and initiating event of chemical incidents from the study. Mechanical failures were cited as leading to 40% of the incidents. Human factors, including both unintentional and intentional acts, were cited in 27% of the reports, while the effects of natural phenomena accounted for only 1% of the incidents. Approximately 29% of the reports had no indication of an initiating event.

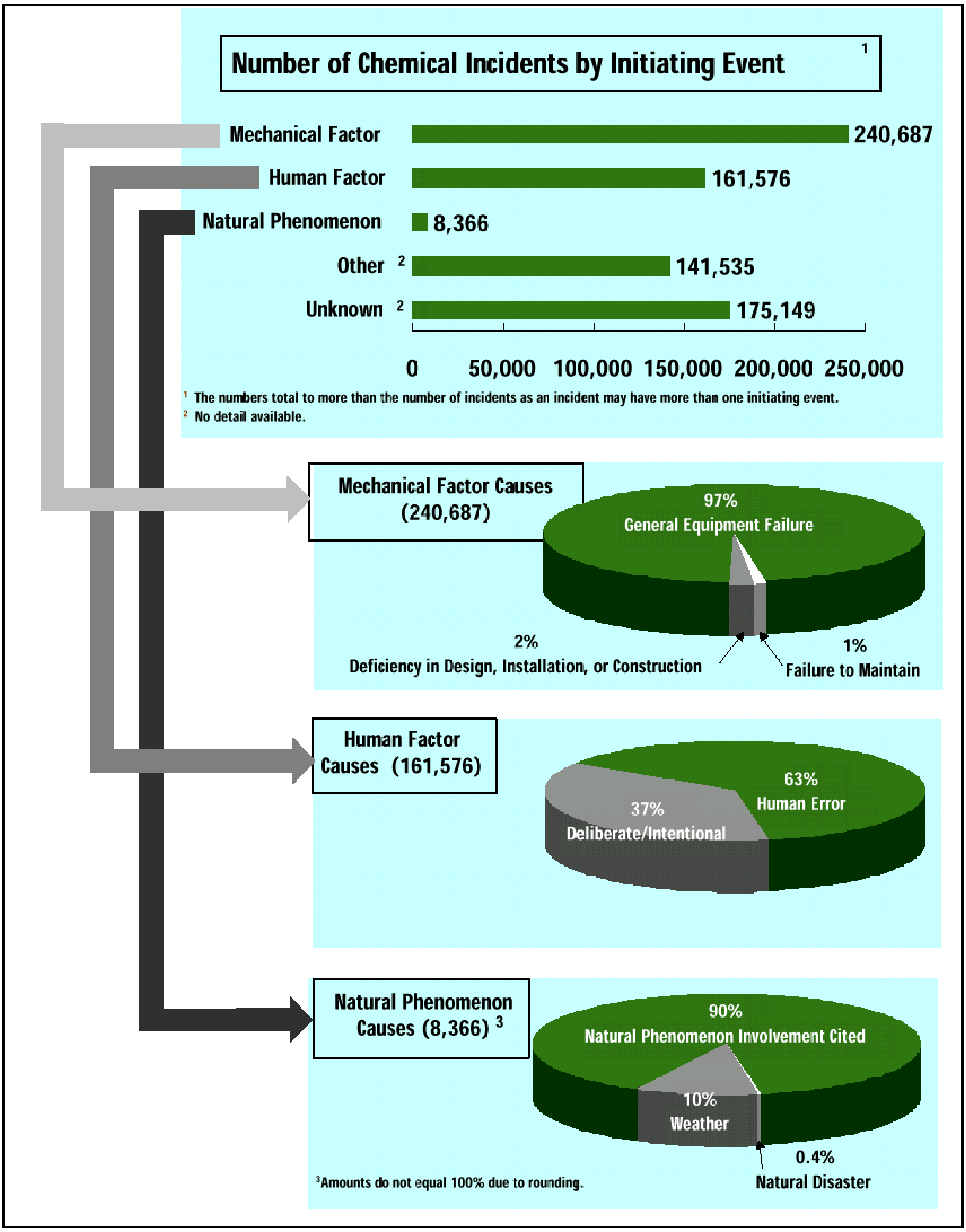


Figure 4-1 Summary of USA chemical incident history (1987 – 1996) by initiating event (Source: CSB Chemical Incident Baseline Study, 1999)

4.4 Generic Equipment Failure Scenarios

In order to characterise the various failure events and assign a failure frequency, fault trees were constructed starting with a final event and working from top down to defining all initiating events and frequencies. A summary of this analysis is given in Appendix D. The analysis was completed using published failure rate data. Equipment failures can occur in tanks, pipeline and other items handling hazardous materials. These failures may result in

- Release of flammable materials and fires upon ignition; and/or,
- Release of to toxic materials.

4.4.1 Storage Tanks

Incidents involving storage tanks include catastrophic failure leading to product leakage into the bund and a possible bund fire. A tank roof failure could result in a possible tank fire. A fracture of the tank nozzle or the transfer pipeline could also result in product leakage into the bund and a possible bund fire.

Typical failure frequencies for atmospheric tanks and pressure vessels are listed below:

Table 4-2 Failure frequencies for atmospheric tanks

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

Table 4-3 Failure frequencies for pressure vessels

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

4.4.2 Process Piping

Piping may fail as a result of corrosion, erosion mechanical impact damage, pressure surge (water hammer) or operation outside design limitations of pressure and temperature. Corrosion- and erosion-caused failures usually result in small leaks, which are detected early and corrected. For significant failures, the leak duration may be of the order of ten to thirty minutes before detection of such events.

The generic leak frequency data for process piping is generally expressed in terms of the cumulative total failure rate per year for a 10m section of pipe for each pipe diameter. Furthermore, the failure frequency normally decreases with increasing pipe diameter.

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

An estimate of the length of the line is obviously required. However as the failure of flanges are assumed to be included in the failure frequency of the pipeline, the minimum length of the pipe is set at 10m

Table 4-4 Failure frequencies for pipes

Description	Frequencies of Loss of Containment for Pipes per meter per year	
	Full bore rupture	**Leak**
Pipeline < 75 mm	$1x10^{-6}$	$5x10^{-6}$
Pipeline 75 mm< diameter< 150mm	$3x10^{-7}$	$2x10^{-6}$
Pipeline >150 mm	$1x10^{-7}$	$5x10^{-7}$

4.4.3 Valves

The failure frequency of valves is dependent on the valve and the leak size. The ratio of the leak size (*d*) to the valve size (*D*) should firstly be determined in order to determine the valve failure frequency per year, for example

d/D	**Leak Frequency (per valve per year)**
0.1	$1.4x10^{-4}$
0.2	$1.9x10^{-4}$
0.5	$2.5x10^{-4}$
1.0	$3.0x10^{-4}$

4.5 Ignition Probability

A release of a flammable material does not automatically result in a fire but may remain as a flammable cloud or pool. The ignition of flammable and combustible is dependant on many factors including the physical property of the material and its location to ignition sources.

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

Cox, Lees and Ang (1990) suggested ignition probabilities based on release rate and the reactivity of the gas or liquid. These are ignition classes are further divided into build-up, residential, industrial and proximity to roads. The Dutch Authorities (IPO 1994) also adopted this methodology.

A summary of their work is given in Table 4-5.

Table 4-5 The probability of ignition.

Substance and Spill Scenario	Probability
Ignition (non built-up area):	
All Flammable Liquids	6.5% per event
Low Reactive Gases:	
< 10 kg/s release	2% per event
< 100 kg/s release	4% per event
> 100 kg/s release	9% per event
Highly Reactive Gases:	
< 10 kg/s release	20% per event
< 100 kg/s release	50% per event
> 100 kg/s release	70% per event
Ignition (built-up residential area)	100% per event
Ignition (industrial)	50% per event
Ignition (near roads):	
< 50 vehicles per hour	50% per event
> 50 vehicles per hour	100% per event

4.6 Physical Properties

A summary of relevant physical properties for the identified hazardous substances are summarised in Appendix B.

5 PHYSICAL AND CONSEQUENCE MODELLING

5.1 Background

It is important to know the difference between hazard and risk. A hazard is anything that has the potential to cause damage to life, the property and the environment. Furthermore, it is a constant parameter (such as petrol, chlorine, ammonia, etc.) that poses the same hazard wherever they are present. Risk, on the other hand, is the probability that a hazard will actually cause damage, and how severe that damage will be. Risk is therefore the probability that a hazard will manifest itself. For instance, the risk of a chemical depends upon the amount present, the process it's used in, the design and safety features of its container, the exposures, the prevailing environmental and weather conditions and so on. Risk analysis thus comprises a judgement of probability based on local atmospheric conditions and generic failure rates, and the severity of consequences based on the best available current technological information.

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

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

Control	*People are more willing to accept risks they impose upon themselves, or they consider to be "natural", than to have risks imposed upon them.*
Dread and Scale of Impact	*Fear is greatest where the consequences of a risk are likely to be catastrophic rather than spread over time.*
Familiarity	*People appear more willing to accept risks that are familiar rather than new risks*
Timing	*Risks seem to be more acceptable if the consequences are immediate or short-term, rather than if they are delayed - especially if they might affect future generations.*
Social Amplification and Attenuation	*Concern can be increased because of media coverage or graphic depiction of events, or reduced by economic hardship.*

Trust	*A key factor is how far the public trusts regulators, policy makers, or industry. If these bodies are open and accountable (being honest, admitting mistakes and limitations and taking account of differing views without disregarding them as emotive or irrational) then the public is more likely to place credibility in them.*

The difficulty in communicating an acceptable risk is therefore not trivial. Furthermore, setting acceptable risk criteria for use in quantitative risk assessments may often also result into disagreement between the various affected parties. Nevertheless, sound arguments have lead to the definition of levels of acceptable risks taking into account the need of people to feel safe in their day-to-day activities, and to be protected from risks ranging from unsafe food to radioactivity exposures.

A risk assessment should be seen as an important component of on-going preventative actions aimed at minimising, or hopefully, avoiding accidents. Re-assessments of risk should therefore follow at regular intervals, and/or after any changes that could alter the hazard, so contributing to the overall prevention programme and emergency response plan of the plant. Risks should be ranked in decreasing severity, and the top risk reduced to acceptable levels.

Predictive hazard evaluation procedures have been developed for analysis of processes when evaluating very low probability accidents with very high consequences (for which there is little or no experience), and more likely releases with fewer consequences, but for which there may be more information available. The concept therefore addresses both the probability of an accident and the magnitude and type of the undesirable consequence of that accident. Risk is usually defined as some simple function of both the probability and consequence.

5.2 Physical and Consequence Modelling

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

The second step is then to estimate the consequences of a spill on humans, fauna, flora and structures. The consequences would be due to the toxicity, thermal radiation and/or explosion overpressures. The consequences may be described in various formats. The simplest methodology follows a comparison of predicted concentrations (or thermal radiation, or overpressures) to short-term concentration (or radiation or pressure) guideline values. In a different, but more realistic fashion, the consequences may be determined by using a dose-response analysis. Dose-response analysis aims to relate the intensity of the phenomenon that constitutes the hazard to the degree of injury or damage, which it can cause. Probit Analysis is possibly the method mostly used to estimate probability of death, hospitalisation or structural damage. The probit is a lognormal distribution and represents a measure of the percentage of the vulnerable resource that sustains injury or damage. The probability of injury or death (i.e. risk level) is in turn estimated from this probit (risk characterisation).

5.3 Fires

Combustible materials within their flammable limits may ignite and burn if exposed to an ignition source of sufficient energy. On process plants this normally occurs as a result of a leakage or spillage. Depending on the physical properties of the material and the operating parameters, the combustion of material in a plant may take on a number of forms i.e. pool fires, jet fires and flash fires.

5.3.1 Thermal Radiation

The effect of thermal radiation is very dependent on the type of fire and duration exposed to the thermal radiation. Codes such as API 520 and 2000 suggest the maximum heat absorbed on vessels for adequate relief designs to prevent the vessel from failure due to overpressure. Other codes such as API 510 and BS 5980 give guidelines for the maximum thermal radiation intensity as a guide to equipment layout.

The effect of thermal radiation on human health has been widely studied with many relations developed relating injuries to the time and intensity of the radiation exposed. Two values normally quoted is 1.5 kW/m^2 or “safe” value where people can be exposed for long period of time and 4.7 kW/m^2 for people performing emergency operation for short periods of time.

Figure 5-1 Thermal Radiation Guidelines (BS 5980 –1990)

Thermal Radiation Intensity (kW/m^2)	**Limit**
1.5	Will cause no discomfort for long exposure
2.1	Sufficient to cause pain if unable to reach cover within 40 seconds
4.5	Sufficient to cause pain if unable to reach cover within 20 seconds
12.5	Minimum energy required for piloted ignition of wood and melting of plastic tubing

Thermal Radiation Intensity (kW/m^2)	Limit
25	Minimum energy required to ignite wood at indefinitely long exposures
37.5	Sufficient to cause serious damage to process equipment

5.3.2 Bund and Pool Fires

The pool fires being either tank or bund fires consist of large volumes of flammable material at atmospheric pressure burning in an open space. The flammable material will be consumed at the burning rate depending on factors including the prevailing winds. During combustion heat will be released in the form of thermal radiation. Temperatures close to the flame centre will be high but will reduce rapidly to tolerable temperatures over a relatively short distance. Any plant building or persons close to the fire or within the intolerable zone will experience burn damage with the severity depending on the distance from the fire and the time exposed to the heat of the fire.

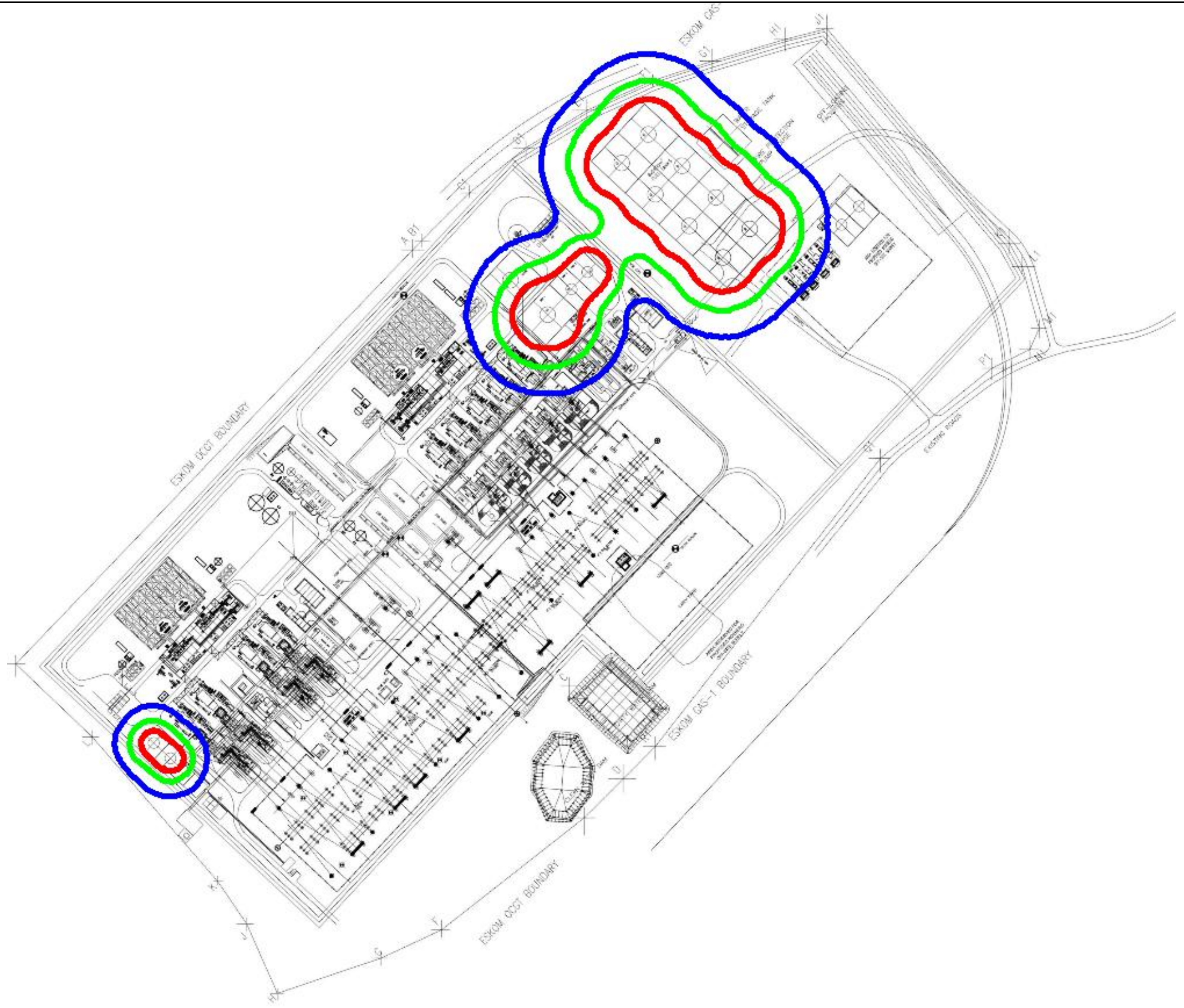
In the event of a pool fire the flames will tilt according to the wind speed and direction. The flame length and tilt angle affect the distance of thermal radiation generated.

- **Bund Fires**

Pool fires were analysed for the loss of containment of diesel in the storage tank bunds and the offloading area assuming an equidirectional wind speed of 10 m/s. The thermal radiation contours from large fires is shown below in Figure 5-2 .

The thermal radiation isopleths from all pool fires combined are shown below in Figure 5-4. The 4.7 kW/m^2 is the radiation that would cause pain and second degree burns with in 20 seconds. This value is used for emergency planning from fires. The 12.5 kW/m^2 is the value that would damage plastics and ignite wood. It is also recognised at the value to cause a 1% fatality with a 20 seconds exposure. The 37 kW/m^2 represents damage to metal equipment. From a personal injury prospective, an exposure to a fire of excess of 35 kW/m^2 would result in spontaneous combustion of clothing with an assumed lethality of 100%.

This distance may reduce if historical meteorological values were used. However the distance between the tank bunds and the perimeter fence should not be reduced without careful consideration to public safety.



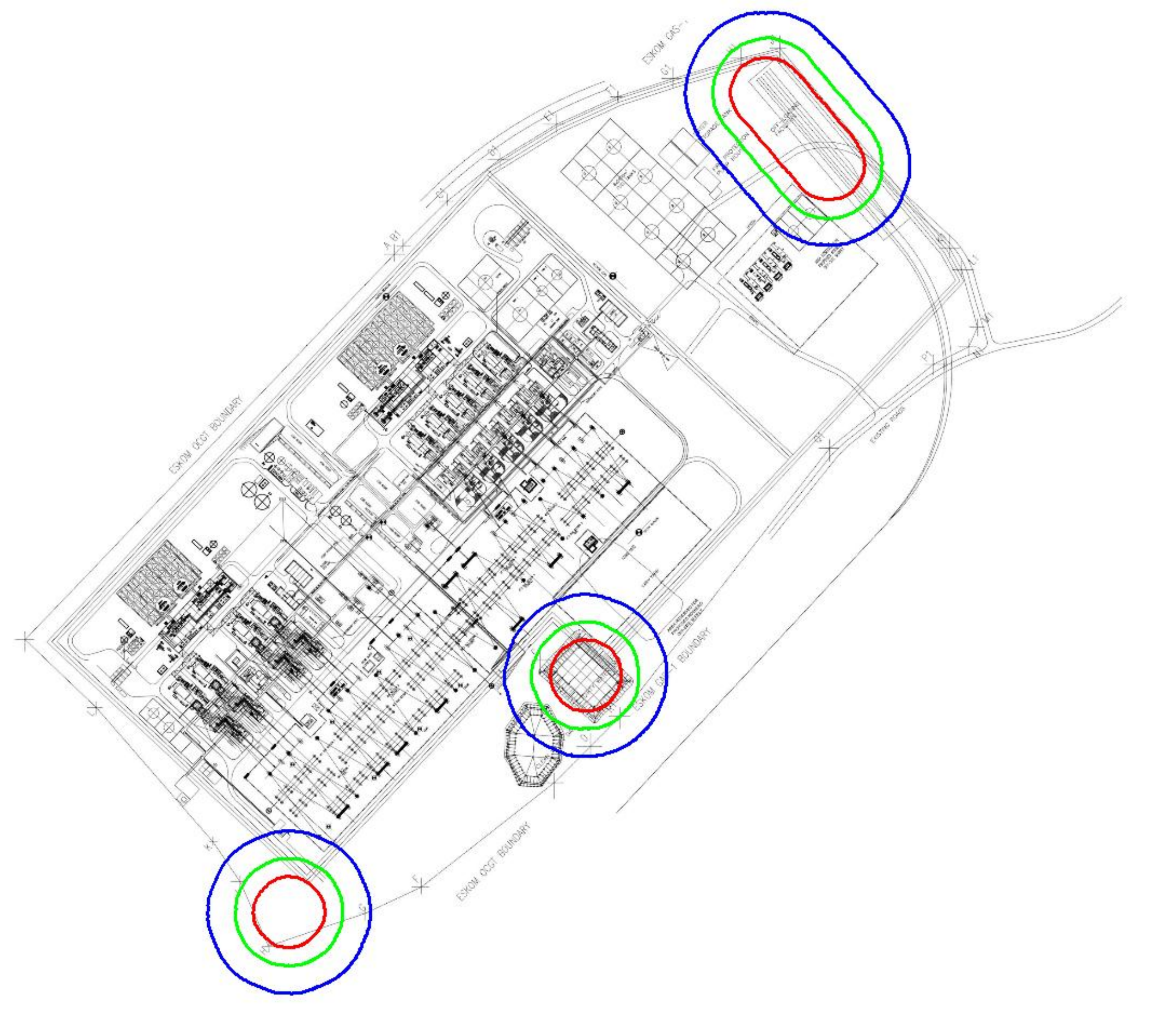
LEGEND	**THERMAL RADIATION (kW/m^2)**
blue line	4.7
green line	12.5
red line	37

Figure 5-2 Thermal radiation from fully developed bund fires

- **Road and Rail Transportation Fires**

The Ankerlig Power Station receives diesel by road tankers which are offloaded in dedicated areas. Spillages from the offloading operation will be caught in drains and directed to the Dirty Dams where the hydrocarbons would be separated from water. Fires in the offloading area would be of short duration as the residue fuel on the floor was consumed. The major fire would occur at the Dirty Dams where large quantities of diesel could be present. The thermal radiation of 37 kW/m^2 and 12.5 kW/m^2 could extend beyond the boundary of the site with potential offsite consequences. However the area of offsite consequences is small with health adults evading the dangers

The delivery of fuel to site via rail taners was considered in this study. This study assumed a maximum offloading capacity of 10 rail tankers simultaneously with the spilt material allowed spreading to a maximum area of 1200 m^2. In the event of a delayed fire, the maximum thermal radiation would be depicted in Figure 5-3. As the fuel is consumed, the fire would decrease until the entire spilt diesel was consumed.



LEGEND	THERMAL RADIATION (kW/m^2)
Blue line	4.7
Green line	12.5
Red line	37

Figure 5-3 Thermal radiation from as a result of offloading operations

- **Propane Pool Fire**

Propane is a gas under atmospheric temperatures and pressures. The propane is kept as a liquid due the high pressure within the storage vessel. A loss of containment of liquid propane would result in a portion of the material vaporising with the liquid material forming a pool at the boiling point temperature. As with uncontained liquids the pool would spread until it could spread no more or it is contained by a natural barrier.

On ignition of an unconfined flammable pool, the fire would extend to the limit of the pool but would shrink rapidly as the fuel within the pool is consumed.

The thermal radiation isopleths from all pool fires combined are shown below in Figure 5-4. The 4.7 kW/m^2 is the radiation that would cause pain and second degree burns with in 20 seconds. This value is used for emergency planning from fires. The 12.5 kW/m^2 is the value that would damage plastics and ignite wood. It is also recognised at the value to cause a 1% fatality with a 20 seconds exposure. The 37 kW/m^2 represents damage to metal equipment. From a personal injury prospective, an exposure to a fire of excess of 35 kW/m^2 would result in spontaneous combustion of clothing with an assumed lethality of 100%.

The thermal radiation from propane pool fires would not have direct offsite impacts and requires no further investigation.

LEGEND	THERMAL RADIATION (kW/m²)
Blue line	4.75
Green line	12.5
Red line	37

Figure 5-4 Thermal radiation from propane pool fires

5.3.3 Jet fires

Jet fires occur when flammable material of a high exit velocity ignites. In process industries this may be due to design (flares) or accidental. Ejection of flammable material from a vessel, pipe or pipe flange may give rise to a jet fire and in some instances the jet flame could have substantial “reach”. Depending on wind speed, the flame may tilt and impinge on pipelines, equipment or structures. The thermal radiation from these fires may cause injury to people or damage equipment some distance from the source of the flame.

Propane is a flammable gas under atmospheric conditions. At a temperature of 30°C the pressure exerted would be approximately 10.6 bar to maintain a liquid phase. In the event of a release in the gas phase, propane will initially escape at a high rate at the operating temperature. However, the temperature of the bulk liquid propane drops rapidly with an associated decrease in the vapour mass flow rate. Assuming the worst case from a nozzle failure of 40 mm, the initial flow rate of butane would be in the critical flow regime with a flow rate of 2.2 kg/s. Should the released gas ignite, a maximum flame length of 20.4 m would form. The thermal radiation of the jet fire would decrease rapidly from the flame. Damage to equipment and personnel injuries would occur from direct impingement from the flame

5.3.4 Flash Fires

A loss of containment of flammable materials would mix with air and form a flammable mixture. The cloud of flammable material would be defined by the Lower Flammable Limit (LFL) and the Upper Flammable Limit (UFL). An ignition within a flammable cloud can result in an explosion if the front is propagated by pressure. If the front is propagated by heat, then the fire moves across the flammable cloud at the flame velocity and is called a flash fire. In some instances pockets of flammable clouds may extend beyond the LFL due to localised conditions. The ½ LFL endpoint assumes there are no isolated pockets and that ignition would not occur beyond this point.

- **Propane**

The flammable distances for propane releases are shown in Table 5-1.

Table 5-1 Flammable distances for propane releases

Scenario	Maximum Distance to LFL (m)	Maximum to ½ LFL (m)
50 mm Vapour hole (largest vapour nozzle)	51	21
Catastrophic storage tank failure	186	283
Catastrophic failure –delivery tanker 20 m^3	268	394

Figure 5-5 shows the maximum flammable limit from a catastrophic failure of the 20 m^3 delivery tanker. Under worst case, the flammable cloud could extend some distances to an ignition point. In the event of a large release, people should be removed from the danger areas and all potential ignition sources removed from the area.