Appendix F

Preliminary Hazard Analysis

Contents

Executive Summary

Introduction

In December 2008, TRUenergy commissioned the Tallawarra Stage A Combined Cycle Gas Turbine (CCGT) power station at Yallah, NSW. This station has a nominal operating capacity of 400 MW and is supplied with natural gas via a lateral line from the Eastern Gas Pipeline which runs from the west of the site. The Tallawarra Stage A plant has recently entered commercial operation.

TRUenergy is also seeking approval for the construction and operation of the Tallawarra Stage B power station. The Stage B power station will be either a single CCGT station with a nominal capacity of 400 MW or two Open Cycle Gas Turbines (OCGT) with a nominal capacity of 300 to 450 MW.

As part of turbine operations, the Stage B plant will store, handle and use a number of dangerous goods that are classified by the Australian Dangerous Goods Code (ADG 2008). Hence, under the requirements of State Environmental Planning Policy No.33 (SEPP 33), a Preliminary Hazard Analysis (PHA) is required to demonstrate that the proposed facility is only potentially hazardous and not hazardous. This section summarises the results of the PHA study which covers the dangerous goods stored handled and used at the power station and the fitting line supplying the natural gas fuel to the power station. The study does not cover the following:

1) The high voltage electrical transmission lines due to the nature of this facility and the minimal hazardous impact on the community; and
2) The transmission pressure pipeline called the Tallawarra Gas Lateral that supplies gas to the gas receiving station at the site. The pipeline risk assessment was completed and approved as part of the Tallawarra A project.

Methodology

The methodology selected for the study was that recommended by the NSW Department of Planning (DoP) in Multi Level Risk Assessment (DIPNR, 1997). This approach assesses each hazard at the site and determines whether there is a potential for offsite impact. Those incidents determined to have a potential offsite impact are assessed for consequence severity and the results compared to consequence criteria published by the DoP. The incidents identified to have no offsite impact are not included in further assessment. Those incidents identified to exceed offsite consequence criteria are carried forward for frequency and risk analysis. The results of the frequency and risk analysis are then compared to risk criteria, published by the DoP, and those incidents exceeding risk criteria are subjected to risk reduction measures. Risks are then reviewed and the process continued until risks are below acceptable criteria.

Brief Description of the Project

The Stage B CCGT power station will consist of one gas turbine unit producing a total power output of up to a nominal 400 Megawatts (MW). The open cycle gas turbine peaking power station will consist of two gas turbine (GT) units producing a total power output of up to a nominal 450 Mega Watts (MW). The proposed site is currently located in an area zoned 5a "special use" under the Wollongong LEP, in which the location of a power station is permissible. Under the draft Wollongong LEP the area will be zoned SP2 Infrastructure and development for the purposes of electricity generation will also be permissible within this zone.

As well as the gas turbine unit, the site will also contain electrical power supply equipment in the form of transformers and switchyards. The station will be fuelled by natural gas, transferred by the Eastern Gas Pipeline (EGP). The site will also contain shared ancillary facilities with the approved Tallawarra Stage A power station, including water storage and treatment, control room and amenities. For the OCGT plant only, the site would contain a diesel storage tank (back up fuel supply).

As part of the power station development, it is likely that the following dangerous goods will be stored, handled and used:

No.	Type of Goods	Nature of the Material	DG Class	Packaging Group	Qty Proposed for Storage (m^3 or kg)
1	Natural Gas (methane)	Flammable Gas	2.1	III	No storage
2*	Diesel Fuel	Combustible Liquid	C1	-	2000m^3
3	Lubricating Oil**	Combustible Liquid	C2	-	20m^3
4	Transformer Oil***	Combustible Liquid	C2	-	65m^3

* For the OCGT plant only
**Per oil tank
***Per transformer

Hazard Analysis

A detailed hazard analysis was conducted, including the development of a hazard identification table (see **Appendix A**). The results of the hazard analysis identified a number of incidents that had the potential to have an impact offsite. These were:

- Gas fitting line incident leading to gas leak as a result of external interference;
- Gas leak into the gas turbine enclosure, ignition and explosion/jet fire;
- Diesel fuel leak into the gas turbine enclosure, ignition and pool fire;
- Oil leak into the gas turbine enclosure, ignition and pool fire;

- Transformer oil leak, oil ignition and pool fire in the bund surrounding the transformer;
- Diesel fuel storage tank fire;
- Diesel fuel storage bund fire;
- Diesel delivery/transfer pool fire; and
- Contaminated fire water release.

These incidents were carried forward for consequence analysis. All other incidents assessed were identified to have no potential for offsite impact and were not carried forward.

Consequence Analysis

A detailed consequence analysis was conducted for each of the incidents listed in the previous section (see **Appendix B** to this report). The analysis identified that only five incidents had the potential to impact offsite, these were:

- **Gas fitting line incident -** Leading to gas fitting line breach from external interference and fitting line rupture due to the high operating pressure (5,300kPa or 53bar). This is described in **Section 5.2.** The resultant jet fire was identified to have a fatality impact exceeding the published criteria at the boundary of a nominal gas fitting line corridor (nominally 10m wide). The jet fire was identified to reach over 100m in impact distance, resulting in fatality impacts outside of a nominal 10 metre wide corridor but within TRUenergy property. Hazardous Industry Planning Advisory Paper No.4 (DIPNR 1992c) indicates that the maximum permissible heat radiation impact at the boundary is 4.7kW/m^2. Hence, as this value was exceeded, this incident was carried forward for further analysis;
- **Gas leak into the gas turbine enclosure, ignition and explosion/jet fire -** This incident was identified to result in an explosion overpressure of 10kPa or 0.1bar at the nearest site boundary. HIPAP No.4 indicates that explosion overpressure in the order of 10kPa would not result in fatality. HIPAP No.4 also indicates that at 10kPa, damage could occur to buildings and structures. However, the closest site boundary is at the lakeside and there are, and will be, no structures constructed in this area. Although there is no chance of fatality as a result of 10kPa overpressure, HIPAP No.4 indicates that there is a 10% probability of injury as a result of overpressure in the order of 7-14kPa. Hence, this incident has been carried forward for further analysis (injury potential).
- **Diesel fuel storage bund fire -** The heat radiation analysis conducted for this incident identified that at the site boundary, closest to the diesel storage, the heat radiation level from a diesel tank bund fire was 0.28kW/m^2. HIPAP No.4 indicates that the maximum permissible heat radiation impact at the boundary is 4.7kW/m^2. Hence, as this value was not exceeded, this incident was not carried forward for further analysis.

- **Diesel Fuel Delivery/Transfer Fire** – The heat radiation analysis conducted for this incident identified that at the site boundary, closest to the diesel transfer point, the heat radiation level was $0.12kW/m^2$. HIPAP No.4 indicates that the maximum permissible heat radiation impact at the boundary is $4.7kW/m^2$. Hence, as this value was not exceeded, this incident was not carried forward for further analysis.
- **Contaminated Fire Water Release** – It was identified that in the event of a fire, applied fire water may become contaminated with the fire products. The consequence analysis indicated that, based on the NSW Best Practice Contaminated Water Retention Guidelines, it would be necessary to contain $498.6m^3$ of potentially contaminated fire water on site. A recommendation has been made regarding the capacity of the first flush retention pond, based on the likely application rate and period of application (described in **Section 5.6**). Adoption of this recommendation would result in the need for no further assessment of this incident.

All other incidents assessed for consequence were related to fire and heat radiation impact. The assessments indicated that the level of heat radiation at the site boundary from each incident was below the criteria published in HIPAP No.4 (DIPNR 1992c).

Frequency Analysis

A detailed frequency analysis was conducted for the two incidents carried forward for further assessment. The results of the analysis for each incident is summarised below:

- Frequency of a gas fitting line rupture due to external interference was estimated to be – $1x10^{-5}$ p.a.
- Frequency of an explosion due to an ignited gas leak into the turbine enclosure was estimated to be – $9.5x10^{-6}$ p.a.

Risk Analysis

- **Gas fitting line rupture** – The gas fitting line incidents would occur in the nominal fitting line easement to the south of the turbine area. A pipeline failure (rupture) and ignition would result in the jet flame being directed parallel to the pipeline, with heat radiating from the flame towards the area adjacent to the piperack. The heat radiation impact at $23kW/m^2$ occurs at a distance of 54 metres. Buildings and structures on site are within the heat radiation envelope and therefore may be impacted by the incident, resulting in a domino effect. The domino risk for the proposed development was calculated to be 0.3 pmpy, which is well below any established criteria for offsite impacts.

  In the event of a gas line fitting rupture, there is also potential for delayed ignition and flash fire. The flash fire fatality risk was calculated as 8.75x10-8 pmpy. Therefore, the risk at the site boundary and the closest residential area is below the published risk criteria of 1 pmpy.

- **Explosion in turbine enclosure** – In the event of an explosion, there would be insufficient overpressure at the buffer zone boundary to cause fatalities. However, there would be sufficient pressure to cause injuries. The injury risk as a result of a turbine enclosure explosion is 0.158 pmpy. The accepted injury risk at residential areas is 50 pmpy and therefore this criterion is not exceeded.

Based on the analysis conducted in this study, the proposed gas turbine power station is classified as only potentially hazardous and not hazardous and, hence, is permissible in the area currently zoned 5(a) "Special Use" or in the proposed zoning of SP2 Infrastructure.

Recommendations

During the analysis conducted in this study, a number of recommendations were made. These are summarised below.

1) During the analysis, a number of assumptions were made regarding the effectiveness of the fire safety and gas detection systems, the construction of the facility and adequacy of the location of the safety systems, the operability of the equipment and interaction with operators on site, response to emergencies and adequacy of control systems (hardware and software). These assumptions were made due to the preliminary nature of the analysis and the plant design. To ensure the effectiveness of the proposed plant safety systems, it is recommended that the following studies be completed as part of the ongoing assessment prior to commencement of operations:

- Hazard and Operability Study, in accordance with HIPAP No.8 (DoP 1995a) - on completion of the final system design;
- Fire Safety Study, in accordance with HIPAP No.2 (DIPNR 1992d) - prior to commencement of operations;
- Emergency Response Planning in accordance with HIPAP No.1 (DIPNR 1992e) - prior to commencement of operations;
- Final Hazard Analysis (DoP 1994) – on completion of final design and prior to commencement of operations;
- Safety Management System assessment in accordance with HIPAP No.9 (AS 2004b) - prior to the commencement of operations; and
- Hazard Audit within 12 months of commencement of operations in accordance with HIPAP No.5 (DoP 1995b)

2) It was identified that consequence impacts as a result of gas fitting line impact from external interference such as plant collision could result in fitting line rupture due to the high pressure of the gas conveyed to the site. Hence, in the event of a jet fire or flash fire incident there will be an

immediate impact offsite resulting in fatalities where people are close to the fire. It is recommended that:

- The gas fitting line should be marked indicating "HIGH PRESSURE GAS PIPELINE". The distance between the markers should be no more than 20m; and
- A safety management system element should be developed specifically for the fitting line; this element should include regular fitting line route and equipment inspections (every 5 years). It was identified that in the event of fire, there is a potential for contaminated fire water to escape off site, resulting in environmental damage. To minimise the risk of this occurrence, it is recommended that the site first flush retention pond be designed to contain a minimum of 498.6 m^3. This will ensure the fire water, applied in accordance with the applicable Australian Standards, is retained on site.

Abbreviations

Abbreviation	Description
ADG	Australian Dangerous Goods Code
ALARP	As Low As Reasonably Practicable
AS	Australian Standard
bar	1 atmosphere or 101.325kPa
CCGT	Closed Cycle Gas Turbine
DG	Dangerous Goods
DoP	Department of Planning
EGIG	European Gas Pipeline Incident Data Group
EGP	Eastern Gas Pipeline
HDPE	High Density Poly Ethylene
HIPAP	Hazardous Industry Planning Advisory Paper
HP	High Pressure
HV	High Voltage
IBC	Intermediate Bulk Container
ISO	International Standards Organisation
kg	kilograms
kL	kilo Litres
kL/d	kilo Litres per day
km	kilometre
km/yr	kilometre per year
kV	kilo Volts
kVA	kilo Volt Amps
kW/m^2	kilo Watts per square metre
LEL	Lower Explosive Limit
M	metres
m/s	metres per second
m^3	cubic metres
MAOP	Maximum Allowable Operating Pressure
MLRA	Multi Level Risk Assessment
Mm	millimetres
MPa	Mega Pascals
MW	Mega Watts
NG	Natural Gas
NOx	Nitrous Oxide
OCGT	Open Cycle Gas Turbine
p.a.	per annum
PG	Packaging Group
PHA	Preliminary Hazard Analysis

pmpy	per million per year
QRA	Quantitative Risk Assessment
SEPP	State Environmental Planning Policy
UFL	Upper Flammable Limit

1. Introduction

1.1. Background

In December 2008, TRUenergy commissioned the Tallawarra Stage A Combined Cycle Gas Turbine (CCGT) power station at Yallah, NSW. This station has a nominal operating capacity of 400 MW and is supplied with natural gas via a lateral pipeline from the Eastern Gas Pipeline which runs from the west of the site. The Tallawarra Stage A plant has recently entered commercial operation.

TRUenergy is seeking approval for the construction and operation of the Tallawarra Stage B power station. The Stage B power station will be either a single CCGT station with a nominal capacity of 400 MW or two Open Cycle Gas Turbines (OCGT) with nominal capacity of 300 – 450 MW.

As part of the power station operation, a number of dangerous goods will be stored and handled at the site, resulting in a requirement of the facility to be assessed under State Environmental Planning Policy (SEPP) No.33, "Hazardous and Offensive Industries". SEPP 33 requires a Preliminary Hazard Analysis (PHA) to be conducted for the site to demonstrate that the proposed power station is only potentially hazardous and not actually hazardous.

TRUenergy has commissioned Sinclair Knight Merz (SKM) to prepare the PHA study for the proposed Stage B power station. This document reports on the findings of the PHA study.

1.2. Objectives

The objectives of the study are to:

- prepare a PHA study for the proposed power station in accordance with the requirements of Hazardous Industry Planning Advisory Paper (HIPAP) No.6, Hazard Analysis Guidelines (DIPNR 1992b); and
- report on the findings of the study for submission to the regulatory authority in support of the Development Application.

1.3. Scope of Work

The scope of work is for a PHA study of the proposed power station, and natural gas transmission fitting line supplying fuel within the site, at Yallah, NSW. The study includes the assessment of potential hazards associated with the storage and use of dangerous goods at the proposed site and the potential offsite impact exceeding the risk criteria published in HIPAP No.4, Risk Criteria for Land Use Safety Planning (DIPNR 1992c).

The scope includes the assessment of dangerous goods at the proposed Stage B power station and the supply of natural gas contained in a fitting line within the facility boundary. The assessment of chemicals used for water treatment has not been included in this assessment as they are part of the Tallawarra Stage A power station (refer to **Figure 3-3**). The power transmission lines are also not included in this assessment as they are not considered a major hazard to the surrounding land uses due to the location of the lines within a protected easement and the fact that these lines do not have the propensity to develop hazards that have the potential to "domino", resulting in large scale offsite impact.

2. Methodology

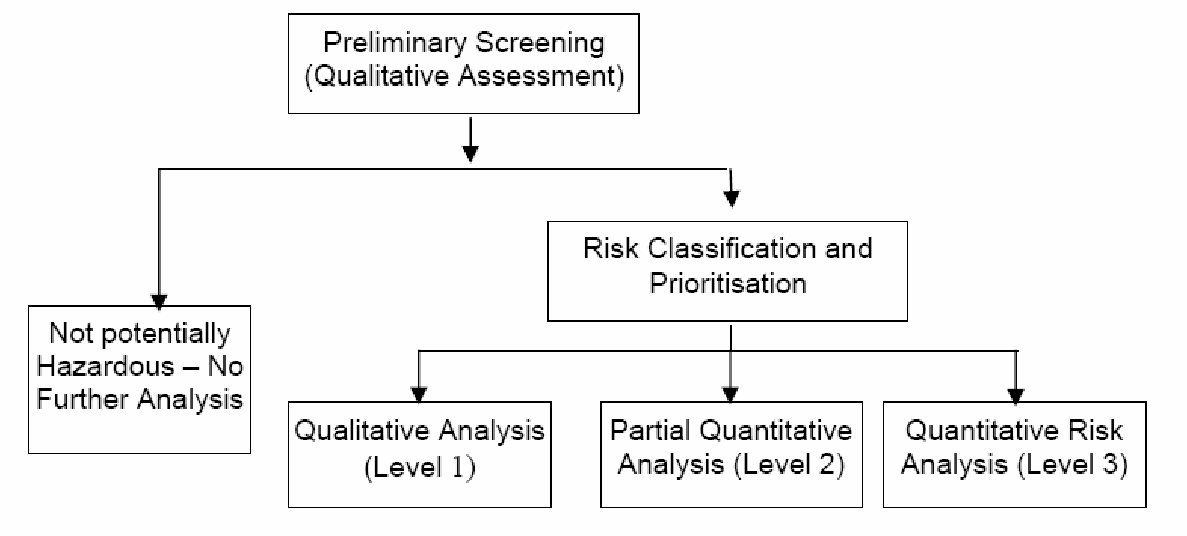
2.1. General Approach

The NSW Department of Planning (DoP) Multi Level Risk Assessment (DIPNR 1997) approach was used for this study. The approach considered the development in context of its location and its technical and safety management control. The Multi Level Risk Assessment Guidelines are intended to assist industry, consultants and the consent authorities to carry out and evaluate risk assessments at an appropriate level for the facility being studied.

The Multi Level Risk Assessment approach is summarised in **Figure 2-1**. There are three levels of assessment, depending on the outcome of preliminary screening. These are:

- **Level 1 – Qualitative Analysis**, primarily based on the hazard identification techniques and qualitative risk assessment of consequences, frequency and risk;
- **Level 2 – Partially Quantitative Analysis**, using hazard identification and the focused quantification of key potential offsite risks; and
- **Level 3 – Quantitative Risk Analysis (QRA),** based on the full detailed quantification of risks, consistent with Hazardous Industry Planning Advisory paper No.6 – Guidelines for Hazard Analysis.

Figure 2-1 The Multi Level Risk Assessment Approach



The "Applying SEPP 33" (DoP 1994) guideline may also be used to assist in the selection of the appropriate level of assessment. This guideline states the following:

"It is considered that a qualitative PHA may be sufficient in the following circumstances:

- *where materials are relatively non-hazardous (for example corrosive substances and some classes of flammables);*
- *where the quantity of materials used are relatively small;*
- *where the technical and management safeguards are self-evident and readily implemented; and*
- *where the surrounding land uses are relatively non-sensitive.*

In these cases, it may be appropriate for a PHA to be relatively simple. Such a PHA should:

- *identify the types and quantities of all dangerous goods to be stored and used;*
- *describe the storage/processing activities that will involve these materials;*
- *identify accident scenarios and hazardous incidents that could occur (in some cases, it would also be appropriate to include consequence distances for hazardous events);*
- *consider surrounding land uses (identify any nearby uses of particular sensitivity); and*
- *identify safeguards that can be adopted (including technical, operational and organisational), and assess their adequacy (having regards to the above matters).*

A sound qualitative PHA which addresses the above matters could, for some proposals, provide the consent authority with sufficient information to form a judgement about the level of risk involved in a particular proposal".

The proposed Stage B power station will consist of two distinct phases; construction and operation. The land uses will be quite different in these stages; the construction will have a relatively light population and will be under the control of the project management team constructing the facility. Hence, the land use surrounding the power station will be relatively non-sensitive and the technical and management safeguards are readily implemented, controlled and monitored both by the project management team and TRUenergy. Under these circumstances, it is considered that a qualitative assessment would be adequate to cover the management of the site during the construction period and the safeguards required for implementation to ensure risks are in the "as low as reasonably practicable" (ALARP) range. The only potential major hazard would be the connection of the gas supply pipeline to the existing high pressure transmission gas lateral pipeline to the west. Assessments such as Construction Safety Study would be considered adequate to cover the risks associated with the construction at the site. It is therefore recommended that a Construction Safety Study be conducted for the project using the guidelines issued by DoP in HIPAP No.7 (DIPNR 1992a).

Once construction of the power station is completed, it will then operate independently of the original construction phase and will be occupied, during operational periods, by a working population. It is in this phase that hazardous incidents could impact the surrounding land use and, hence, a more detailed risk assessment would be required. As the dangerous goods stored on site are relatively low in quantity (in comparison to the levels listed in “Applying SEPP 33” (DoP 1994), a level two MLRA approach has been selected for this component of the study.

2.2. Detailed Approach

The detailed study approach follows that recommended in HIPAP No.6, “Hazard Analysis Guidelines” (DIPNR 1992b). The approach is summarised below.

2.2.1. Hazard Analysis

A detailed hazard identification was conducted for all site operations described in Section 3. Where an incident was identified to have potential offsite impact, it was included in the recorded hazard identification word diagram (Appendix A of this report). The hazard identification word diagram lists incident type, causes, consequences and safeguards. This was performed using the word diagram format suggested in HIPAP No.6 (DIPNR 1992b). Each postulated hazardous incident was assessed qualitatively in light of proposed safeguards (technical and management controls). Where a potential offsite impact was identified, the incident was carried forward for further analysis. Where the qualitative review in the main report determined that the safeguards were adequate to control the hazard, or that the consequence would obviously have no offsite impact, no further analysis was performed.

2.2.2. Consequence Analysis

For those incidents qualitatively identified in the hazard analysis to have a potential offsite impact, a detailed consequence analysis was conducted. The analysis modelled the various postulated hazardous incidents and determined impact distances from the incident source. The results were compared to the criteria listed in HIPAP No.4 (DIPNR 1992c). Where an incident was identified to result in offsite effects, it was carried forward for frequency analysis. Where an incident was identified to have an offsite effect and a simple solution was evident (i.e. move the proposed equipment further away from the site boundary), the solution was recommended and no further analysis was performed.

2.2.3. Frequency Analysis

If a simple solution for managing consequence impacts were not evident, each incident identified to have potential offsite impact was subjected to a frequency analysis. The analysis considered the initiating event and the probability of failure of the safeguards (both hardware and software).

2.2.4. Risk Assessment

As the selected approach for this analysis was a Level 2 assessment (DIPNR 1997), where incidents were identified to impact offsite and where a consequence and frequency analysis was conducted, the consequence and frequency analysis for each incident would be combined and compared to the risk criteria published in HIPAP No.4 (DIPNR 1992c). Where the criterion was exceeded, a review of the major risk contributors was performed. Recommendations were then made regarding risk reduction measures.

3. Description of the Proposed Stage B Power Station

3.1. Land Zoning and Adjacent Land Uses

Figure 3-1 shows the regional location if the proposed Stage B power station in Yallah, NSW. The Stage B power station would be located adjacent to Tallawarra Stage A power station which was recently commissioned. Both the Tallawarra Stage A and Stage B power stations would be situated within the Tarrawarra lands area, which is approximately 1.8 km north-east of the Southern Freeway. **Figure 3-2** shows the site location within the Yallah area.

The area in which the site located is zoned 5(a) "Special Uses" under the Wollongong LEP and the proposed Stage B power station is permissible with development consent in this zone. Under the draft Wollongong LEP the area will be zoned SP2 Infrastructure and development for the purposes of electricity generation will also be permissible within this zone.

The power station site will be located in an area of currently open countryside, with no industrial facilities currently located within the zoned area. However, it is likely that future development in the area would result in the power station being located within an industrial area contained in the Tallawarra lands. The closest existing residential zones are about 1km to the north, and about 2km west of the site, although under the draft LEP for the area the residential zonings will be within 145m to the north west and 175m to the north east.

3.2. Proposed Description

For the CCGT plant, it is intended that one CCGT unit would be installed although the final CCGT design had not yet been selected. For the OCGT plant, it was understood that two OCGT units would to be installed and that the final OCGT design had not yet been selected. The PHA has assumed, therefore, a typical OCGT and CCGT unit comprising of common components found in all options under consideration. This will not adversely affect the study outcomes as all gas turbines will use the same fuel and service supplies (e.g. gas, oil, etc.). **Figure 3-3** shows a typical site layout of the CCGT power station. **Figure 3-4** shows a typical site layout of the OCGT power station. The proposed station will be typically powered by gas turbines and will generate electricity for supply to the national grid. The OCGT plant only will contain a diesel fuel backup system. A summary of the typical main plant components is given below:

Gas Turbine Facility - Air inlet filter

- Air compressor plant

- Combustors

	- Gas Turbines
	- Exhaust Stacks
	- Power Generator
	- Generator Circuit Breaker
	- Mains Transformer (oil filled)
Gas Fitting line	- Fitting line inlet facility
	- Fitting line delivery facility
Transmission Line	- 132 kV Electrical substation complete with HV switching facility
Ancillary Services	- Backup fuel storage (diesel)/tanker unloading facility
	- Station supply transformers (nominal 1500 kVA – dry type)
	- Air compressor plant
	- Lubricating and hydraulic oil system
	- Stormwater system
	- Fire protection
	- Control Room, Workshop & Amenities

The facilities listed above are described in more detail in the following sections.

3.2.1. Gas Turbines

The proposed CCGT power station development is to comprise a nominal 400 MW closed cycle gas fired power generation facility. The station will utilise one closed cycle gas fired turbine unit (unit type yet to be determined). The turbine will normally operate on natural gas. The gas turbine will be installed within an acoustic enclosure that will limit noise on the outside of the enclosure to meet the regulatory requirements.

The proposed OCGT power station development will comprise a 450 MW open cycle gas fired peaking power generation facility. The station will utilise two open cycle gas fired turbine units (unit type yet to be determined). The turbines will normally operate on natural gas; however they will be equipped for operation on distillate fuel if the gas supply fails. Each gas turbine will be installed within an acoustic enclosure that will limit noise on the outside of the enclosure to below the regulatory requirements.

The gas turbine cycle operates by initially compressing air using a turbine fan which forces the air into a series of combustion chambers where the fuel is injected into the air stream and ignited. The combusted gas then passes across an expansion turbine, which is connected by shaft to the compressor and a generator or alternator that produces the power for the production of electricity.

The use of gas as the primary fuel supply does not require the storage of this fuel on site, and therefore the hazards are minimised. However, using diesel fuel as a back-up fuel source for the OCGT plant requires storage of the fuel in two aboveground tanks located in the north east corner of the site.

The gas turbines and generator/alternator require lubrication (e.g. bearings) and each engine will be fitted with a lubricating oil tank of about 20,000L capacity. The tank will be installed on the outside of the gas turbine acoustic enclosure and will be fitted within a bunded area around the tank. Any leaks from the tank will be contained within the immediate area of the tank.

3.2.2. Electricity Distribution

Two generating units will be connected to one three winding group transformer. The three group transformers will be connected to the132 kV switchyard on site.

Two oil filled transformers will be installed on site, each containing 65,000L of oil. Each transformer will be installed in a bunded area with the capacity to contain the full oil contents of the transformer.

3.2.3. Diesel Fuel Storage and Transfer (OCGT only)

For the OCGT plant only, distillate fuel will be stored on-site in an above ground sealed storage tanks and delivered by road tanker on an as needs basis. This fuel serves as a backup fuel supply for the power station in the event that gas supply is interrupted. There will be two 1,000,000L tanks located in the north east corner of the site. The tanks will supply up to 20 hours of operation.

The storage facility will be designed and constructed in accordance with best practice for dangerous goods storage facilities and bunded in accordance with AS1940-2004: The storage and handling of flammable and combustible liquids. Hence, in the unlikely event of spillage, the release will be contained on site and within the immediate tank area.

At this stage fuel will be delivered to site by bulk 2 B-double (55,000kL) tankers (this point will require verification upon selection of final unit type). The fuel storage area will be constructed with a dedicated fuel transfer point which will be bunded to contain any spills that may occur during the transfer of fuel between the tanker and the tank. Fuel will be transferred using truck mounted transfer pumps. Tanker operator/drivers will transfer the fuel between the tanker and the tank, remaining in the immediate vicinity of the transfer area during all transfer operations.

3.2.4. Potable Water

Water is required for fire fighting, normal domestic requirements on site and sundry industrial cleaning tasks. It may also be required for injection into the gas turbine when the proposed secondary (emergency back-up) fuel is used, to reduce the NOx emissions. In this case the water is treated on site by a demineralisation plant.

To cater for the possibility of an extended interruption of the town water supply to the power station, or a failure in the demineralisation plant, an approximate 200kL raw water storage tank and 500kL demineralised water storage tank has been installed as part of Tallawarra Stage A but will be available to the Stage B project. The raw water storage tank will also function as a supply of water for firefighting purposes. The capacity of the tanks will be optimised following selection of the gas turbine to be used for the project.

3.2.5. Control Room, Workshop & Amenities

A single building will be constructed on the Tallawara Stage A site to house the central control room, the site workshop facilities and site amenities. The control room will provide a central control facility for the both the Stage A and Stage B power stations. All site operations will be controlled from the main panels in the control room.

3.2.6. Gas Supply

High pressure natural gas will be used as the main fuel source for the Stage B power plant and a high pressure fitting line will be built as part of the project. The above ground fitting line will be designed to comply with requirements of AS2885 - 1997, Pipelines: Gas and Liquid Petroleum. The proposed gas fitting line route is shown in **Figure 3-3**.

The proposed natural gas would be supplied from an extension to the existing lateral pipeline in Tallawarra Stage A which connects the power station to the Eastern Gas Pipeline (EGP) and operates at up to 14,895kPa or 149bar. From the gas receiving station the fitting line will be routed along the piperack structure as indicated in **Figure 3-3**.

It is understood the pressure reducing and metering station (PRMS) for Stage B will be located adjacent to the Stage A PRMS. At the time of this PHA gas fitting line specifications were unavailable, but the Stage B gas supply fitting line specifications have been assumed to be 355mm diameter, with a wall thickness of 12.7mm, and constructed from steel (XGrade) and would be routed along the piperack as indicated in the layouts below.

The fitting line will be electrically isolated from facilities and earthing systems installed to AS4853 Electrical Hazards on Metallic Pipelines. Marker signs will be installed on the fitting line in accordance with AS2885.1. This will minimise potential external impact on the fitting line.

3.2.7. Staffing & Hours of Operation

Once operational the Stage B plant will require an increase in the number of existing personnel to manage the day-to-day routine operations and maintenance. For an OCGT plant, approximately 1-3 additional personnel will be required. A CCGT plant will require an additional 15-20 personnel.

3.2.8. Safety Systems

To ensure potential incidents are detected and mitigated, the site will be fitted with a number of detection and protection safety features. These are summarised below.

- **Fire Hydrants** – a fire main and fire hydrants will be installed throughout the site. The fire main system will be installed in accordance with the requirements of AS2419-2005, Fire Hydrant Installation.
- **Fire Hose Reels** – fire hose reels will also be installed on site to provide a first attack fire fighting system. As hydrants will not be fitted with hoses (the use of hoses is the domain of the Fire Brigades only), hose reels will be the main first attack fire fighting equipment on site.
- **Extinguishers** – fire extinguishers will be installed throughout the site. Extinguishers will be installed in accordance with AS2444-2001, Portable Fire Extinguishers and Fire Blankets – Selection and Location. Extinguishers selection and location will be made to suit the anticipated fire conditions in the area where the extinguisher is located.
- **Gas Detectors** – methane gas detectors will be installed in each of the gas turbine enclosures. The detection of gas in a specific enclosure will automatically shut the external gas feed valve to the gas turbine, shutting off gas supply to the enclosure itself. The gas detector will be calibrated to alarm as 5% of lower explosive limit (LEL) of gas in air and shut down gas supply at 50% LEL.
- **Bunding** – all dangerous goods and combustible liquids (lubricating oil, acids and alkalis) will be fitted with bunding to AS1940 (AS 2004a) to prevent spill release beyond the immediate area of the spill.
- **Gas Fitting Line Corrosion Protection –** the high pressure gas fitting line will be painted for corrosion protection.
- **External Interference Protection** –The fitting line will be installed in a sturdy pipe rack that is clear of through traffic.

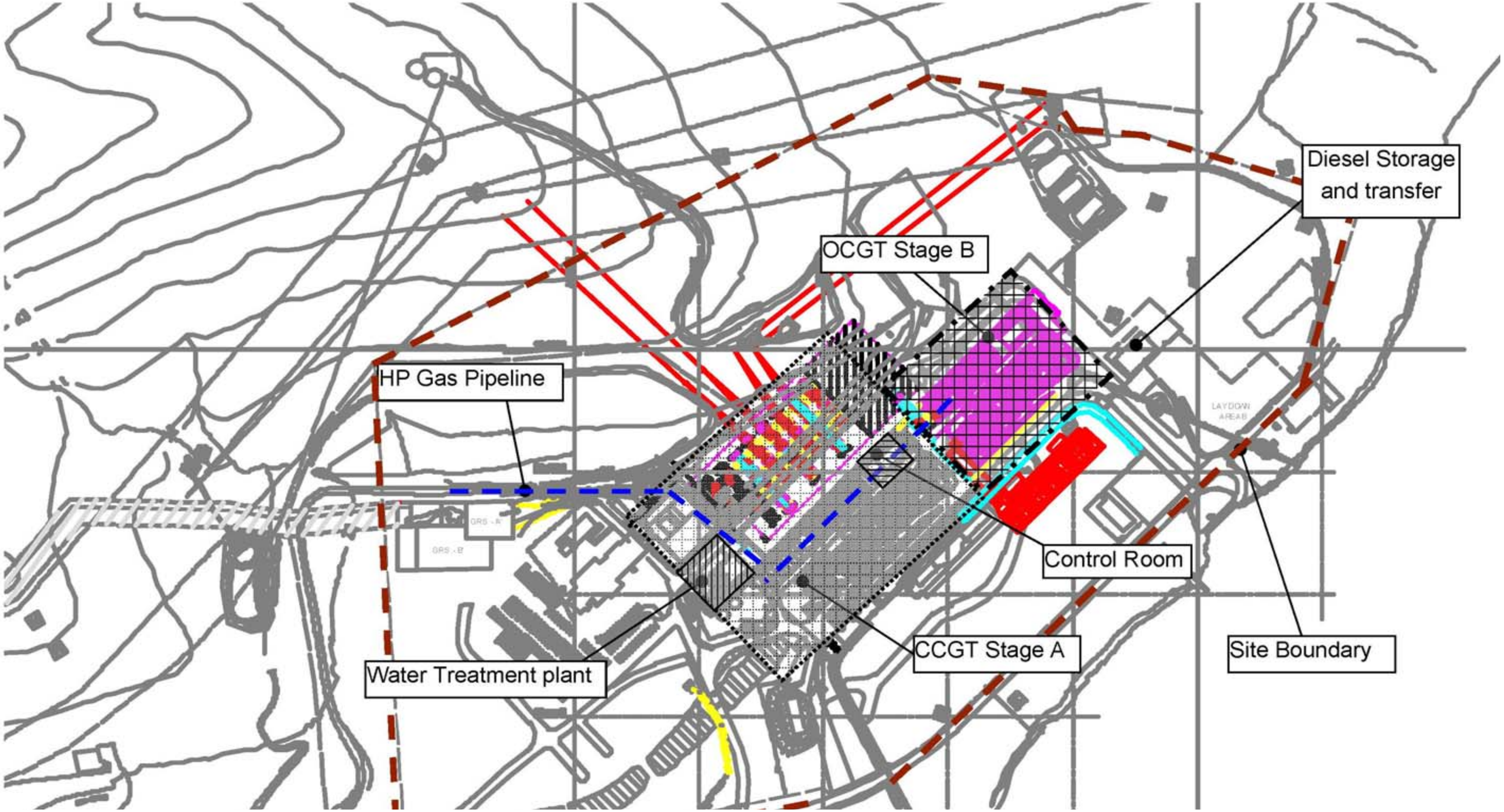
- **Fitting Line Material** – the fitting line will be constructed from X42-grade steel, of 12.7mm wall thickness which will minimise the potential for crack growth propagation in the event of a fitting line breach (i.e. impact). This minimises the potential for continued crack growth and incident propagation.

- **Figure 3-1 Regional location of the proposed power station**

■ **Figure 3-2 Location of the power station Yallah area, NSW**

- **Figure 3-3 Site layout of typical combined cycle gas turbine power station**

- **Figure 3-4 Figure 3-5 Site layout of typical open cycle gas turbine power station**



4. Hazard identification

4.1. General Hazards

A hazard identification table has been developed and is presented at **Appendix A**. Those hazards identified to have a potential impact offsite are detailed in the following section of this document.

4.2. Hazardous Properties of Materials Stored and Used

Table 4-1 lists the type and classes of dangerous goods proposed for storage and used at the gas turbine facility in Yallah, NSW. The nature of each material is listed in **Table 4-1**.

- **Figure 4-1 Dangerous goods stored and used at the Tallawarra Stage B CCBT Power Station, Yallah, NSW**

No.	Type of Goods	Nature of the Material	DG Class	Packaging Group	Qty Proposed for Storage (m^3 or kg)
1	Natural Gas (methane)	Flammable Gas	2.1	III	No storage
2*	Diesel Fuel	Combustible Liquid	C1	-	2000m^3
3	Lubricating Oil**	Combustible Liquid	C2	-	20m^3
4	Transformer Oil***	Combustible Liquid	C2	-	65m^3

* OCGT only

**Per oil tank (2 tanks)

***Per transformer (2 transformers)

The nature of the dangerous goods stored and handled at the proposed gas turbine site (Tallawarra Stages A & B) fall into three categories; flammable/combustible liquids, corrosive liquids and flammable gas. However, only flammable and combustible liquids will be stored at the Stage B site. Potential hazards associated with each storage and handling operation are detailed below.

4.2.1. Natural Gas

The inherent hazards of the fitting line arise from the flammability of the natural gas, and the pressure at which it is transmitted and processed in the station. The types of hazardous incident which may occur, in theory at least, would all require a leak in the fitting line or associated equipment (e.g. valves, meters, flanges, etc.). They are:

- fire;
- flash fire; and/or
- explosion.

However, it is noted that natural gas is lighter than air (i.e. a buoyant gas) and if released tends to rise and disperse rather than accumulate forming a flammable cloud.

A hazard identification table has been developed at **Appendix A**. This table has been used as the basis for the hazard analysis below.

4.2.2. Diesel Fuel (OCGT only)

Diesel fuel is classified by AS1940-2004 (AS 2004a) as a C1 combustible liquid as the fuel has a flash point between 60.5oC and 150oC. A combustible liquid will burn if the temperature of the liquid exceeds the flash point and the vapour generated at the liquid surface is ignited. The resultant incident is a pool fire that radiates heat to the surrounding area resulting in potential equipment damage and or injury/fatality.

Diesel fuel is also a contaminant to the biophysical environment and releases can damage sensitive environmental areas surrounding storages in the event a leak occurs and escapes to the environment. Diesel fuel will also float on water and be carried a significant distance from a leak point by a water course.

4.2.3. Lubricating Oil

Lubricating oil is classified by AS1940 (AS 2004a) as a C2 combustible liquid as the oil has a flash point in excess of 150oC. Like C1 combustible liquids, should the temperature of the fluid exceed the flash point, the oil vapour may be ignited resulting in a pool fire. A combustible liquid will burn if the temperature of the liquid exceeds the flash point and the vapour generated at the liquid surface is ignited. The resultant incident is a pool fire that radiates heat to the surrounding area resulting in potential equipment damage and or injury/fatality.

Lubricating oil is also a contaminant to the biophysical environment and releases can damage sensitive environmental areas surrounding storages in the event a leak occurs and escapes to the environment. Lubricating oil will also float on water and be carried a significant distance from a leak point by a water course.

4.2.4. Transformer Oil

Transformer oil has similar characteristics to lubricating oil. The flash point of transformer oil is in excess of 150oC; hence, the oil is classified as a C2 combustible liquid. The consequences of spills are the same as those explained in **Section 4.2.2**.

4.3. Detailed Hazard Identification

The following section constitutes detailed qualitative hazard identification for those incidents listed in **Appendix A** of this report.

4.3.1. Gas Fitting line

The following fitting line design and operational details, below, were assumed:

- Operating Pressure – 5,300kPa or 53bar (52.3 atmospheres);
- Diameter – 273mm;
- Wall thickness – 12.7mm; and
- Material – X42 Grade Steel.

There is historical evidence of gas transmission pipeline failure both in Australia and overseas. Historical evidence (Bolt, R. & Horalek, V. 2004) indicates that there are a number of factors that can lead to fitting line leak and subsequent release of gas. The details below summarise those incidents that have historically led to fitting line failure and gas release:

- **External Interference** – external interference accounts for the majority of release incidents in gas transmission fitting lines (Bolt, R. & Horalek, V. 2004)). Forklifts, excavators, front end loaders, and other mechanical equipment can strike fitting lines in pipe racks leading to gas release, ignition and jet fire. At this stage of development in the area there are few if any adjacent operations. Hence, there is a low likelihood of external impact. However, as the area develops there is a higher likelihood that excavation or other contact will occur in the area and the pipeline may be affected. The fitting line is internal to the power station and of 12.7mm wall thickness that will withstand external interference. All work carried out at site will be controlled by a permit system and will be supervised. The pipe rack is of robust design and is clear of any through traffic. However, external impact has been carried forward for further analysis.
- **Flood Damage** – this may occur where the fitting line traverses river beds or water courses. The potential for fast running water could lead to scouring above the fitting line exposing the pipe to potential impact from rocks and debris moving in the water stream. In addition, surface flooding could lead to the fitting line floating from the trench, leading to fitting line damage. A review of the fitting line route (shown in **Figure 3-3**) indicates that the fitting line will be laid away from water courses on the existing Stage A above ground pipe rack corridor. Hence, this hazard has not been carried forward for further analysis.
- **Subsidence Damage** – where fitting lines are installed near or in banks and levees, wash away may expose the fitting line and uneven weight could cause severe fitting line damage. However, the fitting line is not installed in a bank or levee and therefore, incidents resulting from subsidence have not been carried forward for further analysis

- **External Corrosion Damage** – many soils are acidic and fitting lines installed without external protection are susceptible to corrosion and eventual failure (leaks). The fitting line is not installed underground and hence is not exposed to acidic soils reducing the potential for external corrosion to negligible levels. Incidents involving external corrosion (excluding impact) have not been carried forward for further analysis.
- **Internal Corrosion Damage** – the introduction of corrosive gas to the fitting line could result in accelerated corrosion or moisture in the gas could lead to corrosion impact on the pipe internal surface. However, gas is fed from the EGP and the gas is dry and non-corrosive, having passed over 1000kms through this line. Hence, the likelihood of corrosion from this source is considered negligible. Incidents as a result of corrosion have therefore not been carried forward for further analysis.
- **Faulty Material** – the use of faulty materials, such as fitting line with manufacturing defects, could lead to premature fitting line failure resulting in rupture. However, pipe material will be purchased from a quality assured organisation (i.e. ISO9001, AS (2004c), which minimises the potential for faulty materials. Further, the fitting line will be fully tested in accordance with the requirements of AS2885 (AS 2007), including a pressure test to prove fitting line will operate safely and without failure at maximum allowable operating pressure (MAOP). The quality assurance testing regime required under AS2885 minimises the potential for fitting line failure as a result of material defects. Hence, these potential incidents have not been carried forward for further analysis.
- **Faulty Construction** – like the faulty materials incidents detailed above, faulty construction can also lead to failure of the fitting line. For example, faulty welding can lead to premature failure and gas release. However, fitting line welds will be subjected to X-Ray inspection minimising the potential for failure from this source. Further, the fitting line will be subjected to a testing regime required by AS2885 (AS 2007), further minimising the potential for faulty construction failure. Additional construction problems, such as poor support or alignment in the pipe rack will be minimised by strictly following the requirements of AS2885 (AS 2007). Hence, incidents as a result of faulty construction have not been carried forward for further analysis.
- **Ground Movement** – this may occur where fitting lines are installed in an earthquake zone. Earthquakes and excessive ground movement may lead to damaged pipe racks and buckled pipework or, in the worst case, rupture. However, the fitting line would not be installed in an earthquake zone. The Illawarra area is relatively stable and earthquakes of the magnitude that could result in fitting line rupture are rare and, hence, the risk is considered negligible. Incidents as a result of earthquake of excessive ground movement have not been carried forward for further analysis.
- **"Hot Tap" by Error** "– "hot tap" is the connection to a live gas line during operation. When this is conducted by expert personnel the risk is negligible. However, failure to identify a live gas fitting line and attempts, by error, to connect to this fitting line could lead to fitting line

breach and gas release. To identify gas fitting line, marker signs will be installed on the fitting line in accordance with AS2885.1. This incident has, therefore, not been carried forward for further analysis.

The above analysis is supported by the results of studies conducted by the European Gas Pipeline Incident Data Base (Bolt, R. & Horalek, V. 2004), which conducts research into gas pipeline incidents both in Europe and overseas. The results of these studies indicate that the majority of pipeline incidents (50%) occur as a result of external interference.

4.3.2. Gas Release in the Gas Turbine Enclosure

Natural gas fuel, supplied by a fitting line from the main supply line, is used to supply the gas turbines. The fuel is piped internally within the turbine enclosure and, hence, any leaks of gas would have the potential to accumulate within the enclosure resulting in the formation of a flammable gas cloud. Ignition of such a cloud could result in explosion and significant damage to the enclosure as well as offsite impact from explosion overpressure and/or “missiles” projected from the destruction of parts of the enclosure.

To minimise the potential for such an incident, the gas turbine enclosure will be fitted with ventilation, which will continually provide air exchange within the enclosure. Hence, any leaks will be diluted to below lower flammable limits (LEL) and discharged from the enclosure. Further, the enclosure will be fitted with a hydrocarbon detector, which will activate level alarms and initiate gas turbine fuel supply shut down (from outside the enclosure). Hence, any leaks will either be diluted and or isolated before reaching potentially hazardous levels.

Notwithstanding the fact that detection and protection measures have been installed, in the event such measures fail, there is a potential for an explosion within the enclosure and jet fire at the leak source. Hence, explosion and fire incidents at the gas turbine enclosure have been carried forward for further analysis.

4.3.3. Transformers

Transformers are used to convert electrical power from one volt/amp value to another to facilitate power matching with the national grid and for power supply to specific electrical components on and offsite. Transformers generate significant amounts of heat and require insulation between winding circuits. Insulation between circuits and heat removal is performed by an oil circuit, which passes fluid (oil) around the transformer internal components and then cools the oil externally. It is proposed to install two main transformers at the power station each containing about 65,000L of oil. Leaks and spills of oil can escape beyond the immediate area of the transformer and, in the worst case reach the environment. However, at the proposed gas turbine site all transformers will be fully bunded to contain the full oil contents of the transformer. Hence, any leaks or spills will be contained on site and there will be no environmental release as a result of leaks in this area.

In the event of continued release from a transformer, the oil level in the transformer will fall, exposing the transformer windings and removing the insulating/cooling properties of the oil. This would eventually lead to overheating and potential ignition of the oil and oil vapour inside the transformer resulting in explosion and fire. The explosion would cause damage to the transformer casing and release of burning oil to the bund, resulting in bund fire and potential heat radiation impact offsite. The proposed transformer design will incorporate blast walls between each transformer unit preventing damage to adjacent areas on site; however the blast walls may not mitigate heat radiation beyond the site boundary.

Whilst it is recognised that low oil level switches will be installed on all transformers, and a spray/deluge system will be installed over each transformer, in the event the switches fail and the deluge does not effectively operate, there is a potential for the fire to grow and the heat radiation to impact offsite. Hence, fire in the transformer area has been carried forward for further analysis.

4.3.4. Lube Oil (Storage & Turbine Enclosure)

Lubricating oil will be stored in a 20,000L tank adjacent to the turbine enclosure and will be circulated through the engine by a turbine oil pump. The lube oil storage will be bunded and therefore, in the event of an oil line failure or leak, the oil would collect in the bund and be contained on site. No leaks would escape beyond the immediate bund area. It would be necessary to clean up spills as soon as possible, hence, it is recommended that spill kits be installed adjacent to the turbine enclosures to assist in clean up of any spillages of fluids in the enclosure.

Notwithstanding the fact that oil spills would be contained within the bunded areas, in the unlikely event of oil ignition, the oil would burn in the bund resulting in a pool fire in the bund. This may result in the heat radiation impacting the surrounding areas. Hence, this incident has been carried forward for further analysis.

4.3.5. Acid and Alkali Storage

It is understood that the acid and alkali storage will be located in the Tallawarra Stage A water treatment area and, hence, is not within the scope of this PHA. This incident has therefore not been carried forward for further analysis.

4.3.6. Contaminated Fire Water Release

In the event of a fire at the site there is a potential for fire water, applied as a fire control measure, to become contaminated with the burning dangerous goods. A review of the dangerous goods at the site indicates that flammable and combustible liquids are the worst case scenario fires and, in the event of fire, will require the application of foam to the burning liquids. As a surfactant, the foam will emulsify the flammable/combustible liquid to some extent resulting in contamination of the fire water, which if released offsite has the potential to contaminate local creeks land. This incident has been carried forward for further analysis.

4.4. Assumptions made in the Study

As the PHA study is preliminary in nature, many of the detailed designs are not yet complete. Hence, the PHA study has made a number of assumptions in order to complete the analysis, these include the effectiveness of the fire safety and gas detection systems, the construction of the facility and adequacy of the location of the safety systems, the operability of the equipment and interaction with operators on site and the central control room, response to emergencies (both when the site is staffed and un-staffed) and adequacy of control systems (hardware and software).

As plant design firms, it will be necessary assess the effectiveness of the proposed designs in relation to the PHA assumptions. It is therefore recommended that the following studies be completed as part of the ongoing assessment prior to commencement of operations:

- Hazard and Operability Study, in accordance with HIPAP No.8 (DoP 1995a) - on completion of the final system design;
- Fire Safety Study, in accordance with HIPAP No.2 (DIPNR 1992d) - prior to commencement of operations;
- Emergency Response Planning in accordance with HIPAP No.1 (DIPNR 1992e) - prior to commencement of operations;
- Final Hazard Analysis (DIPNR 1992b) – on completion of final design and prior to commencement of operations;
- Safety Management System assessment in accordance with HIPAP No.9 (DIPNR 1992f) - prior to the commencement of operations; and
- Hazard Audit within 12 months of commencement of operations in accordance with HIPAP No.5 (DoP 1995b).

5. Consequence Analysis

5.1. Incidents Carried Forward for Consequence Analysis

The hazardous analysis conducted in Section 4 identified a number of hazards that have the potential to impact upon adjacent offsite areas. These incidents have been carried forward for consequence analysis to determine whether incident impacts have the potential to exceed consequence criteria published in HIPAP No.4 (DIPNR 1992c). Those incidents carried forward for consequence analysis are:

- Gas fitting line incident leading to gas leak as a result of external interference (i.e. impact or other contact with machinery or plant);
- Gas leak into the gas turbine enclosure, ignition and explosion/jet fire;
- Diesel fuel leak into the gas turbine enclosure, ignition and pool fire;
- Oil leak into the gas turbine enclosure, ignition and pool fire;
- Transformer oil leak, oil ignition and pool fire in the bund surrounding the transformer;
- Diesel fuel storage tank fire;
- Diesel fuel storage bund fire;
- Diesel delivery/transfer pool fire; and
- Contaminated fire water release.

Each incident has been assessed in detail in **Appendix B.** A summary of each incident, including assessment results, is presented in the following sections.

5.2. Gas Fitting line Leak

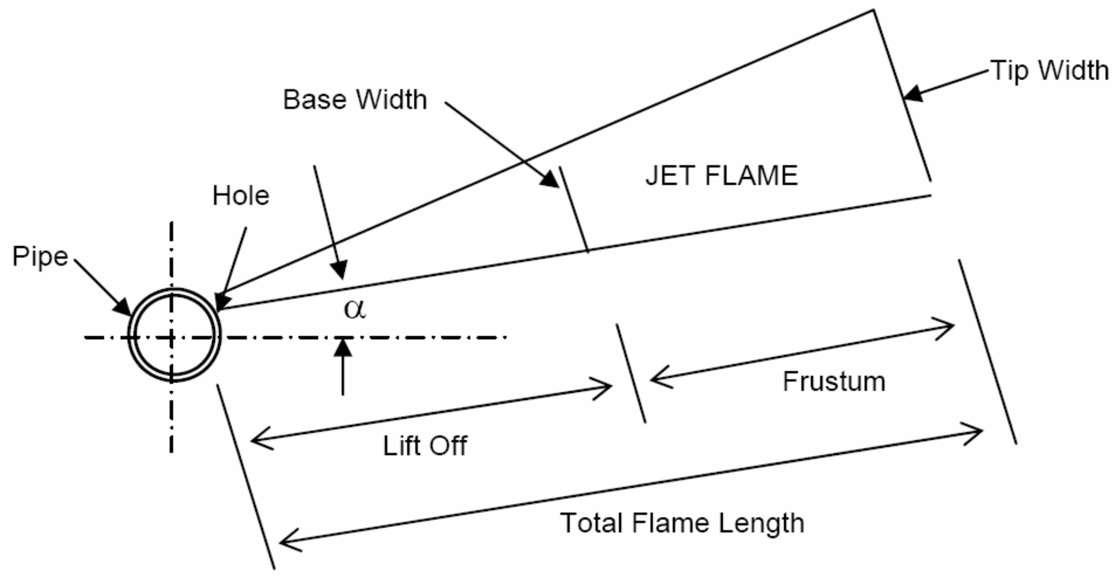
The fitting line hazard analysis conducted in Section 4 identified that external impact was the most likely source of gas fitting line breach. A detailed consequence analysis for fitting line impact failure is conducted in Appendix B of this report, this study identified that external impact on the fitting line could initially result in a hole, with a diameter of 20mm. In the event the fitting line was breached, at a pressure of 5,300kPa or 53bar, the pressure would result in continued crack propagation leading to fitting line rupture. If ignited immediately, a jet fire would result projecting from the fitting line and radiating heat into the surrounding area. **Figure 5-1** shows a typical jet fire schematic, showing flame layout and dimensions.

A heat radiation analysis was conducted and the impacts identified at various distances from the fitting line are reported in **Table 5-1**. **Figure 5-1** may be used to aid in understanding the flame dimensions listed in this table.

- **Table 5-1 Heat radiation impacts from fitting line incidents as a result of jet fire from an external impact breach**

Hole Diameter (m)	Rupture (273mm)
Jet Fire Length-Total (m)	59.13
Width of Flame at End (m)	15.96
Width of Flame at Base (m)	2.26
Flame Lift Off (m)	10.9
Angle of Flame from Horizontal	45^{o}
Heat Radiation Level (kW/m^2)	Distance (m)
35	52.5
23	54.5
15	56
12.5	57
8	59
4.7	61
2	68

- **Figure 5-1 Jet fire schematic**



HIPAP No.4 (AS 2004a) indicates that heat radiation exceeding 4.7kW/m^2 should not impact beyond the site boundary. The nominal easement for the fitting line was considered to be 10m wide; however, the closest site boundary to the pipeline gantry is around 175m. Hence, based on the values in **Table 5-1**, the heat radiation impact to 4.7kW/m^2 will extend beyond the easement boundary (inside the site), but will not impact any offsite areas. Hence, the impact to offsite facilities from a jet fire at the pipeline gantry has not been carried forward for further analysis.

Notwithstanding this, the jet fire has the potential to impact adjacent facilities onsite, resulting in heat radiation in excess of 23kW/m^2, which could result in incident growth leading to eventual offsite impacts. Therefore, jet fire impact to adjacent facilities and the potential for domino incidents has been carried forward for further analysis.

The detailed analysis in **Appendix B** of this report identified that in the event a fitting line breach and subsequent rupture occurred, the gas released from the fitting line may immediately ignite forming a gas cloud that if ignited at a distance and after a time would result in a flash fire, where the cloud burns rapidly but does not explode.

People caught within a flash fire are normally considered fatalities, whilst those outside the confines of the flammable cloud limit are considered safe. It is noted that the gas release from a hole in the fitting line will act as a turbulent jet, entraining air and reducing the downwind impact of release significantly. However, at 5,300kPa or 53bar pressure a significant gas cloud would develop beyond the fitting line easement and therefore ignition of the cloud could result in fatalities beyond the easement limits. It is noted, however that the gas is reasonably buoyant and will rise and dissipate once released. This reduces the potential for delayed downwind ignition and flash fire. Notwithstanding this, a flash fire incident has been carried forward for further analysis.

5.3. Gas Leak into the Turbine Enclosure

In the event of gas leak into the OCGT turbine enclosure, there is a potential for a confined flammable gas cloud to from within the enclosure itself. Ignition of the cloud could lead to explosion due to the confined nature of the enclosure. The detailed consequence analysis conducted in Appendix B calculated the explosion overpressure at specific distances from the gas turbine enclosures at the site. **Table 5-2** summarises the results of the explosion overpressure analysis.

- **Table 5-2 Explosion overpressure versus distance for explosion in the gas turbine enclosure**

Explosion Overpressure (kPa)	Distance (m)
70	48
35	68
14	135
7	180

The closest gas turbine enclosure to the site boundary is Gas Turbine No. 1 which is 150m from the site boundary to the south east (shore line of the lake). Based on the explosion analysis summarised in **Table 5-2**, the explosion overpressure at the site boundary is 10kPa or 0.1bar. HIPAP No.4 indicates that explosion overpressure in the order of 10kPawould not result in fatality. Further, HIPAP No.4 also indicates that at 10kPa damage could occur to buildings and structures. However, the closest site boundary is at the lakeside and there are, and will be, no structures constructed in this area. Although there is no chance of fatality as a result of 10kPa overpressure, HIPAP No.4 indicates that there is a 10% probability of injury as a result of overpressure in the order of 7-14kPa. Hence, this incident has been carried forward for further analysis (injury potential).

5.4. Diesel/Oil Leak into the Gas Turbine Enclosure

An oil leak or diesel fuel leak (OCGT only) will pool into the base of the gas turbine enclosure, or oil will pool in the oil tank bund adjacent to the turbine. Ignition of the leak would lead to a pool fire. A review of the incident consequences indicates that a fire in the gas turbine enclosure resulting in enclosure damage and exposure of the fire to external areas would be the worst case. Hence, this has been the selected postulated incident for this analysis.

In the event of a fire in the gas turbine enclosure the pool fire would eventually cause damage to the enclosure causing enclosure collapse and pool fire/flame exposure beyond the confines of the enclosure walls. The heat radiation would impact upon the surrounding areas and hence an analysis of the flammable/combustible liquids pool fire has been conducted in detail in **Appendix B** of this report. A summary of the analysis results is presented in **Table 5-3**, showing the heat radiation impact from the fire versus the distance from the fire.

- **Table 5-3 Heat radiation impact at selected distances from a gas turbine pool fire incident**

Heat Radiation Impact (kW/m^2)	Distance (m)
35	12.6
23	14.3
15	16.5
12.5	17.5
8	20.7
4.7	25.5
2	37

HIPAP No.4 indicates that heat radiation impact at the site boundary, in excess of 4.7kW/m^2, requires further review for frequency and risk. The closest gas turbine to the site boundary is Gas Turbine No. 1, which is over 150m from the boundary. Based on the analysis results summary presented in **Table 5-3**, it can be seen that the heat radiation at the site boundary is less than 4.7kW/m^2. A review of the potential domino effects from heat radiation impacts on adjacent facilities at levels in excess of 23kW/m^2 indicates that any facilities within 12.6m of the fire could be impacted over an extended period of exposure. The closest facility to the gas turbine oil fire is the diesel tanks which are over 40 m from the fire. Hence, there is a low risk of fire growth from gas turbine oil fires; therefore, this incident has not been carried forward for further analysis.

It is noted that the gas turbine transformer is located directly adjacent to the gas turbine enclosure and, hence, could be affected by the fire. However, a concrete fire wall (FRL 240/240/240) is located between the turbine unit and the transformer, eliminating the potential for fire growth from turbine unit to transformer and vice versa.

5.5. Transformer Leak and Fire

Transformers have been identified (in Section 4) to contain oil, which is classified as a combustible liquid by AS1940 (AS 2004a). Leaks of oil into the bund surrounding the transformer would pool and if ignited result in a pool fire. Heat radiation may impact offsite areas adjacent to the transformer. A detailed pool fire analysis was conducted and is presented in **Appendix B** of this report. A summary of the transformer bund pool fire analysis is presented in **Table 5-4**.

- **Table 5-4 Heat radiation impact at selected distances from a transformer pool fire incident**

Heat Radiation Impact (kW/m^2)	Distance (m)
35	16.5
23	18.3
15	20.8
12.5	22.1
4.7	31.8
2	45

HIPAP No.4 indicates that heat radiation impact at the site boundary (150m), in excess of 4.7kW/m^2, requires further review for frequency and risk. Based on the analysis results summary presented in **Table 5-4**, it can be seen that the heat radiation at the site boundary, 150m away, is below the established criteria and therefore there is no fatality risk at the site boundary.

A review of the potential domino effects from heat radiation impacts on adjacent facilities at levels in excess of 23kW/m^2 indicates that any facilities within 18.3m of the fire could be impacted over an extended period of exposure. The closest facility to the gas turbine transformer fire is the diesel tanks which are over 40m from the fire. Hence, there is a low risk of fire growth from transformer fires; therefore, this incident has not been carried forward for further analysis.

It is noted that the gas turbine transformer is located directly adjacent to the gas turbine enclosure and, hence, the gas turbine enclosure could be affected by the transformer fire. However, a concrete fire wall (FRL 240/240/240) is located between the turbine unit and the transformer, eliminating the potential for fire growth from transformer to the turbine unit and vice versa.

5.6. Diesel Fuel Tank Storage Fire (OCGT only)

For the OCGT plant only, diesel fuel is stored in two 1,000,000L fuel tanks. In the event of a fire in the roof of the tank there is a potential for the roof to collapse resulting in a pool fire in the tank top and heat radiation impact to areas adjacent to the tank. A detailed analysis of the tank fire incident has been conducted in **Appendix B**. A summary of the heat radiation impact levels at selected distances from the tank is presented in **Table 5-5**.

- **Table 5-5 Heat radiation impact at selected distances from a diesel fuel tank fire incident**

Heat Radiation Impact (kW/m^2)	Distance from Tank (m)
35	6.9
23	10
15	13.5
12.5	15.2
10	17.4
8	19.5
4.7	26
2.0	40

HIPAP No.4 indicates that heat radiation impact at the site boundary, in excess of $4.7kW/m^2$, requires further review for frequency and risk. The diesel fuel tank is 135m from the boundary. Based on the analysis results summary presented in **Table 5-6** it can be seen that the heat radiation at the site boundary is less than $4.7\ kW/m^2$. Therefore the impacts from this incident do not exceed the criteria published in HIPAP No.4, and therefore this incident has not been carried forward for further analysis.

In addition to the potential for impact at the site boundary, heat radiation impact levels of $23kW/m^2$ may result in the failure of unprotected steels, and ignition of combustible materials. A review of the closest structure where combustible materials and unprotected steels (i.e. structures) may be present indicates that the OCGT transformer and turbine building would be in the order of 45-60m from the diesel tanks. A review of **Table 5-5** indicates that at 40m the heat radiation impact would be $2kW/m^2$. Hence, there would be no potential for incident growth to adjacent areas from fires in the diesel fuel tanks. This incident has therefore not been carried forward for further analysis.

It is noted that heat radiation from a fire in one tank to the adjacent tank may occur causing damage to the adjacent tank. However, as the tanks are stand-by fuel storages they would contain considerable amounts of fuel at all times (i.e. ensuring readiness for fuel supply in the event of gas supply failure). Heat radiation impact to a full fuel tank does not cause significant damage as the fuel within the tank acts as a heat sink, minimising the potential for tank weakening and failure. Whilst there would be external damage to the tank from the fire/heat impact, structural failure would not occur for considerable time (i.e. long after the adjacent tank fire had been extinguished). Hence, domino incidents to the adjacent tank have not been carried forward for further analysis.

5.7. Diesel Fuel Tank Bund Fire (OCGT only)

In the event of a leak of diesel into the bund, the diesel would pool in the bottom of the bund and if ignited would lead to a pool fire. In the worst case a full bund fire would eventuate, radiating heat into the surrounding area with the potential to impact offsite to the north and west. A detailed bund fire heat radiation analysis was conducted and is reported in **Appendix B**. A summary of the bund fire heat radiation analysis is presented in **Table 5-6**.

- **Table 5-6 Heat radiation impact at selected distances from a diesel fuel tank bund fire incident**

Heat Radiation Impact (kW/m^2)	Distance (m)
23	24.5
15	27.3
12.5	28.8
10	31
8	33.5
4.7	40.5
2	57

HIPAP No.4 indicates that heat radiation impact at the site boundary, in excess of $4.7kW/m^2$, requires further review for frequency and risk. The diesel fuel tank bund is 135m from the boundary. Based on the analysis results summary presented in **Table 5-6** it can be seen that the heat radiation at the site boundary is $0.28kW/m^2$. The heat radiation from a full bund fire, at the site boundary, exceeds the criteria published in HIPAP No.4; hence, this incident has not been carried forward for further analysis.

In addition to the potential for impact at the site boundary, heat radiation impact levels of 23kW/m^2 may result in the failure of unprotected steels, and ignition of combustible materials. A review of the closest structure where combustible materials and unprotected steels (i.e. structures) may be present indicates that the OCGT transformer and turbine building would be in the order of 45-60m from the diesel tanks. A review of **Table 5-6** indicates that at 40m the heat radiation impact would be 4.7kW/m^2. Hence, there would be no potential for incident growth to adjacent areas from fires in the diesel fuel tanks. This incident has therefore not been carried forward for further analysis.

5.8. Diesel Fuel Delivery Area Fire (OCGT only)

In the event of a leak of fuel from diesel transfer filling equipment, the fuel would pool under the leak point and be collected in the transfer point bund. In the event of ignition, a pool fire would result, radiating heat to the surrounding area with potential for impact offsite. A detailed pool fire analysis of the fuel unloading incident has been conducted in **Appendix B**. A summary of the diesel fuel unloading area heat radiation analysis is presented in **Table 5-7**.

- **Table 5-7 Heat radiation impact at selected distances from a diesel fuel unloading area fire incident**

Heat Radiation Impact (kW/m^2)	Distance (m)
35	16.8
23	18.3
15	21.2
12.5	22.5
10	24.3
8	26.3
4.7	32.2
2	46

HIPAP No.4 indicates that heat radiation impact at the site boundary, in excess of 4.7kW/m^2, requires further review for frequency and risk. The diesel fuel unloading area is 135m from the boundary. Based on the analysis results summary presented in **Table 5-7** it can be seen that the heat radiation at the site boundary is <2kW/m^2. This does not exceed the criteria published in HIPAP No.4; hence, this incident has not been carried forward for further analysis.

In addition to the potential for impact at the site boundary, heat radiation impact levels of 23kW/ m^2 may result in the failure of unprotected steels, and ignition of combustible materials. A review of the closest structure where combustible materials and unprotected steels (i.e. structures) may be present indicates that the OCGT transformer and turbine building would be in the order of 45-60m from the diesel tanks. A review of **Table 5-7** indicates that at 46m the heat radiation impact would be 2kW/

m^2. Hence, there would be no potential for incident growth to adjacent areas from fires in the diesel fuel tanks. This incident has therefore not been carried forward for further analysis.

5.9. Contaminated Fire Water Release

In the event of a fire, it will be necessary for fire water to be applied to the incident in order to control the emergency. In many cases fires involve dangerous goods, which have the potential to mix with the fire water and, if released to the environment, result in environmental damage. It will therefore be necessary to contain fire water within the site to prevent potential offsite environmental impact.

In order to determine the quantity of fire water required for retention on site, it is first necessary to determine the quantity of fire water that may be applied to a given incident on site. AS2419 (DoP 1992g) details the required number of hydrants and hoses that would be installed and used in specific situations. Table 3.3 of AS2419 indicates that for an open yard (i.e. a facility like the proposed Gas Turbine Power Station) the number of hydrants and hoses required to fight a fire is 4, for sites with an area in excess of 27,000m^2. The proposed site will have an area in excess of this area, and therefore 4 hoses will be required for this site.

AS2419 lists the flow rate of fire hoses as 10 litres/second or 600 litres/minute. Using this flow rate and the recommended 4 hoses, the total flow rate applied to a fire at the proposed power station is 4 x 600 = 2,400 litres/minute.

A sprinkler and deluge system will be installed in specific location around the transformer. NFPA15 (NRPA 2007) specifies the required fire water application rates for various industrial facilities. For transformers, the application is 10 litres/ m^2/minute, applied over an area of a "…rectangular prism envelope for the equipment and it appurtenances".

The transformer dimensions have been assumed as (final designs have not yet been selected): 16m long x 3m wide x 7m high. The total surface area of the prism would be:

Area of the Transformer Rectangular Prism = 2x(16x7) + 2x(7x3) + (16x3) = 314m^2

Hence, the required fire water application rate is 10 x 314 = 3,140 Litres/minute

The estimated fire water demand for the transformer is 3,140 Litres per minute and the estimated hydrant flow demand is 2,400 Litres/minute. Total fire water requirement is 2,400 + 3,140 = 5,540 Litres per minute.

The NSW Government's Best Practice Guidelines for Contaminated Water Retention and Treatment Systems, requires 90 minutes of fire water to be retained on site. For a fire water application rate of

5,540 litres/minute for 90 minutes, the total fire water required for retention on site is $5.54m^3$ x 90 = $498.6m^3$.

It is understood that the site will be contain a first flush retention pond to contain any spills or first rainfall over the site area. It is therefore recommended that the site first flush/retention pond be designed to retain a minimum of $498.6m^3$**.**

6. Frequency Analysis

6.1. Incidents Carried Forward Frequency Analysis

The consequence analysis indicates that two incidents have the potential to have an impact on offsite areas with severity levels exceeding the criteria published in HIPAP No.4 (DIPNR 1992c). Those incidents carried forward for frequency analysis are:

- Gas fitting line incident leading to gas leak as a result of external interference ; and
- Gas leak into the gas turbine enclosure, ignition and explosion/jet fire;

6.2. Gas Fitting line Incident Frequency Analysis

A review of the pipeline installation and design indicates that the use of data for high pressure gas pipelines may not be prudent, as the pipeline is installed above ground and within a plant area. Hence, the pipeline failure frequency has been assessed using two data sources, including CCPS (CCPS 1989) and University of Sydney (Tweeddale, H.M. 1993). The pipeline failure frequency rate from each data source is:

- In the medium to low range of 0.004 to 0.00006 per section of pipe (per annum) between connections. It is noted that the pipeline will be fully welded along its length, from the point where it enters the plant (metering station) and where it is connected at the gas turbines (CCPS 1989).
- $2x10^{-8}$ L/D per annum (where L = length and D = diameter). Based on a pipeline diameter of 0.273 and a length of pipeline on site of 250m, the failure rate is $2x10^{-8}$ x 250/0.273 = $7x10^{-5}$ p.a. (Tweeddale, H.M. 1993).

A review of the two sets of data indicates that there is some commonality in the failure rate in the range of 10^{-5}. To ensure a conservative assessment, a value of $1x10^{-4}$ has been selected as a pipeline rupture failure rate.

6.3. Gas Turbine Explosion Frequency Analysis

The gas fitting lines inside the gas turbine enclosures deliver fuel to the combustion chambers. The pipework is fully welded, with the exception of sections where valves are installed. At these locations flanges are used to fit the valve into the pipe. Whilst there is negligible likelihood of failure of the pipe (i.e. hole), due to the dry gas, it was identified in the consequence analysis that leaks from flanges and valves could result in build up of gas in the turbine enclosure. However, this would require failure of the gas detection and isolation system and failure of the ventilation fans in the enclosure. In addition, ignition of the gas would also be required. The following failure frequencies have been developed for this analysis.

6.3.1. Flange and Valve Leaks

As this is a preliminary analysis since the detailed design of the gas turbine installation is not yet complete, the number of valves and flanges has been assumed to be 10 valves and 20 flanges, based on similar facilities.

The failure frequency for an external leak in a valve is given as 3.7×10^{-3} per annum (p.a.) (OREDA 2003, Taxonomy 4.3.1.3).

The failure frequency for a leak in a flange is given as 5×10^{-3} p.a. (CCPS 1989, Taxonomy 3.2.1.4).

Total valve leak frequency = single valve leak frequency x no. valves

= 3.7×10^{-3} x 10

= 3.6×10^{-2} p.a.

Total flange leak frequency = single flange leak frequency x no. flanges

= 5×10^{-3} x 20

= 0.1 p.a.

Total leak frequency in the enclosure = flange leak frequency + valve leak frequency

= 0.1 + 0.036

= 0.136 p.a

6.3.2. Fan Failure Frequency

The failure frequency for a fan is given as 2.2x10-3 p.a. (NPRD 1995, page 2-92, Fan Exhaust). Assuming the fan is tested every 6 months (i.e. electrical test, inspection and planned maintenance), the failure probability during operation is estimated using fractional dead time (FDT) theory where:

FDT = ½ λ t

Where: λ = failure rate p.a. (0.0022)

t = 1/no. tests p.a. (1/2)

FDT of fan = ½ x 0.0022 x ½ = 5.5x10-4

6.3.3. Gas Detector & Isolation Valve Failure Frequency

The failure frequency for a gas detector is given as 0.0125 p.a. (OREDA 2003, Taxonomy 4.1.4)

Assuming the gas detector is tested every 6 months, the failure on demand is estimated using fractional dead time (FDT) theory:

FDT of gas detector = ½ x 0.0125 x ½ = 3.125x10-3

The failure frequency for an isolation valve to close on demand (i.e. the emergency shut down or ESD valve outside the enclosure) is given as 0.075 p.a. (OREDA 2003, Taxonomy 4.3.5.4). Assuming the ESD valve is tested every 6 months, the failure on demand is estimated using fractional dead time (FDT) theory:

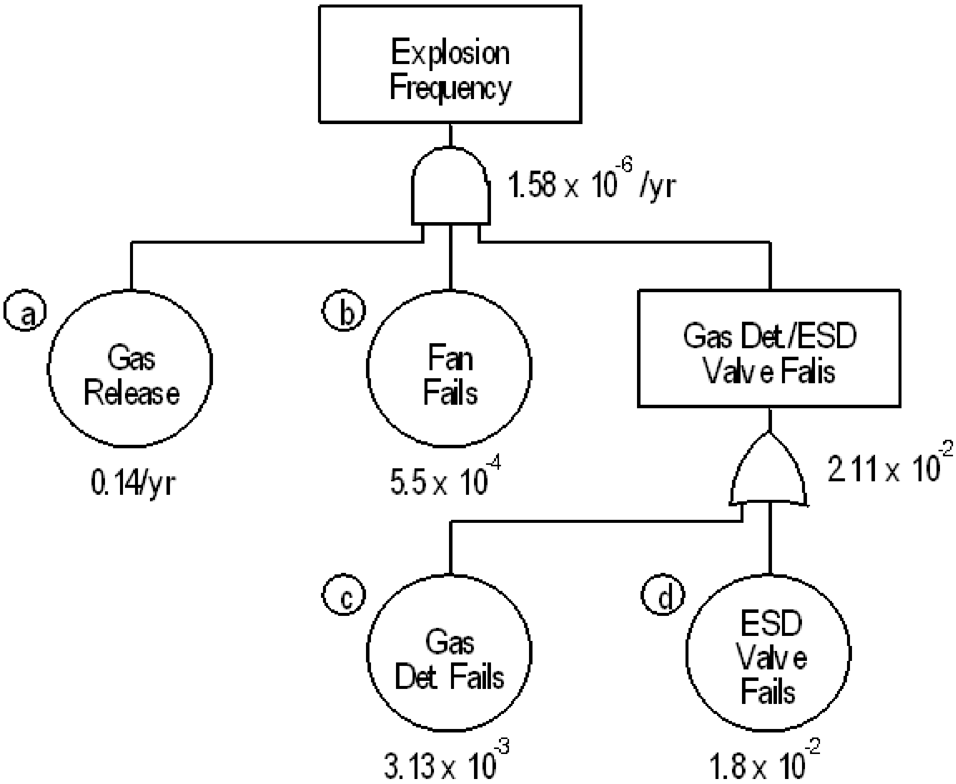
FDT of ESD valve = ½ x 0.075 x ½ = 1.8x10-2

6.3.4. Ignition and Explosion Frequency

The ignition frequency in an enclosed space is given as 0.3 for large releases in excess of 50kg of gas (Cox, A.W. Lees, GF.P. & Ang, M.L. 1991).

The explosion frequency is estimated using a fault tree analysis. **Figure 6-1** shows the fault tree for explosion in the turbine enclosure. The fault tree analysis was conducted using the proprietary software “Faultrease©”, which was developed by Arthur.D.Little in the US. The results of the analysis indicates the explosion frequency (per turbine) to be $1.58x10^{-6}$p.a. For the one CCGT turbine the frequency is $1.58x10^{-6}$p.a. For the two OCGT turbines the frequency is $3.16x10^{-6}$p.a. These values have been carried forward for risk analysis.

- **Figure 6-1 Fault tree analysis – turbine enclosure explosion**



7. Risk Analysis

7.1. Incidents Carried forward for Risk Analysis

- Gas fitting line incident leading to gas leak, immediate ignition and jet fire, as a result of pipeline failure;
- Gas fitting line incident leading to gas leak, delayed ignition and flash fire, as a result of pipeline failure; and
- Gas leak into the gas turbine enclosure, ignition and explosion/jet fire.

These incidents are assessed below for on and offsite impact.

7.2. Gas Fitting line Rupture - Domino Risks

The gas fitting line incidents would occur in the nominal fitting line easement to the south of the turbine area. A pipeline failure (rupture), and ignition, would result in the jet flame being directed parallel to the pipeline, with heat radiated from the flame towards the areas adjacent to the piperack. The heat radiation impact at 23kW/m^2 (the level at which adjacent areas may be impacted – DIPNR 1992c), occurs at a distance of 54m (see **Table 5-1**). Buildings and structures on site are within the heat radiation envelope and, hence, may be impacted by the incident, resulting in a domino effect.

The potential for domino incident is a function of the heat radiation impact and exposure time. In the event a release occurs, and is ignited, the resultant flame would radiate the heat towards the adjacent structures and eventually cause structural failure and or ignition of combustible materials in these areas. However, if the gas supply to the leak is isolated, then the flame will be extinguished before incident growth can occur. The gas supply line to the power station is fitted with a metering and valve station at the site boundary (incoming line), which incorporates an automatic isolation valve that operates on downstream pressure loss in the line. Hence, in the event of a line break (rupture), the automatic isolation will be activated, cutting the gas supply to the leak. The fire will then be extinguished and the domino incident avoided.

Hence, the risk of domino incident is a function of the line failure (rupture frequency), the probability of ignition and the failure of the isolation valve to activate.

The failure rate of a shut down valve to close on demand has been estimated to be 2.5x10^{-3}p.a. (OREDA 2003, Taxonomy 4.4.11). To determine the failure probability of the valve to close on demand, Fractional Dead Time (FDT) theory is used, where:

FDT = ½ λ t where: λ = component failure rate (p.a.)

t = test period (1/no.tests per annum), assumed 1 in this case

Hence, FDT = 0.5 x 2.5×10^{-3} x 1 = 1.25×10^{-3}

For this study, the ignition probability has been selected as 0.3 (Cox *et al* 1991) for massive leaks (>50kg/s) and therefore the domino risk is:

Domino Risk = Ignition probability x leak frequency x probability valve fails to close

= 0.3 x 1×10^{-4} p.a. x 1.25×10^{-3}

= 0.0375 chances in a million per year (pmpy)

The risk of domino incident and onsite impact is extremely low and well below any established criteria for offsite impacts. Hence, in the event of a domino incident occurrence, and potential for fire growth on site causing additional incidents and offsite impact, the incident risk does not exceed the published risk criteria (DIPNR 1992c). In summary, the risks associated with pipeline failure and jet fire are considered "As Low As Reasonably Practicable (ALARP)".

7.3. Gas Fitting Line Rupture – Flash Fire Risk

In the event of a gas fitting line failure (rupture) and gas major gas release, there is a potential for delayed ignition and flash fire. People caught within the envelope of the flash fire would be considered fatalities and those outside the flash fire would not be considered fatalities. As noted in **Section 5**, in the event of a release of natural gas (methane), the gas would rise and dissipate into the atmosphere as the gas is buoyant. Notwithstanding this, if (conservatively), it is assumed that the gas does reach the boundary or residential areas, then delayed ignition and flash fire may result in fatalities in these areas and the probability of fatality would be considered to be 1.

The assessment conducted in **Section 7.2** has estimated the probability of immediate ignition of the gas release to be 0.3. If, conservatively, it is assumed that the probability of delayed ignition is 1-immediate ignition, then the delayed ignition probability is estimated to be 0.7. The flash fire fatality risk at the site boundary or residential areas would therefore be a function of the pipeline failure frequency by the probability of delayed ignition by the probability of failure of the isolation valve to close on demand. Using the values estimated in **Section 7.2** and a delayed ignition probability of 0.7, the fatality risk at the site boundary or residential areas would be:

Flash Fire Fatality Risk = 0.7 x $1x10^{-4}$ p.a. x $1.25x10^{-3}$ = $8.75x10^{-8}$ pmpy.

Hence, the risk at the site boundary and the closest residential areas is below the published risk criteria of 1 pmpy.

Notwithstanding the above assessment, it is noted that in the event of a fire or flash fire incident there may be an impact offsite. Hence, to ensure the risks are maintained in the ALARP range, the following recommendations are made:

- The gas fitting line be clearly marked with “HIGH PRESSURE GAS PIPELINE” at regular intervals (20m) to ensure that personnel working in the area (especially on the piperacks) understand that a high pressure gas fitting line is present.
- A safety management system element be developed specifically for the fitting line maintenance and inspection, this element should include regular fitting line route and equipment inspections on a regular basis.

7.4. Turbine Explosion Injury Risk

A review of the distance from the turbines to the fenced site boundaries indicates that, as a result of the postulated explosion in the turbine enclosure, explosion overpressure at the fence line surrounding the site exceeds 100kPa (see **Table 5-2**). However, the power station site boundaries extend well beyond the fenced area and a buffer zone has been established around these sites such that no industrial, residential or commercial developments can be established within a specific distance of the power station site. The analysis conducted in the study identified that in the event of an explosion, there would be insufficient overpressure at the buffer zone boundary to cause fatalities. However, the analysis indicated that there would be sufficient pressure to cause injuries.

The explosion assessment conducted in **Section 5** indicates that at the closest residential area on the boundary of the buffer zone, the explosion overpressure would result in an injury probability of 10% (0.1) (DIPNR 1992c). The explosion frequency has been estimated to be $1.58x10^{-6}$ p.a.

Injury Risk (Turbine Enclosure Explosion) = 0.1 x 1.58x10-6 = 0.158 pmpy.

HIPAP No.4 (DIPNR 1997) indicates that the accepted injury risk at residential areas is 50 pmpy, hence, the criteria is not exceeded in this case.

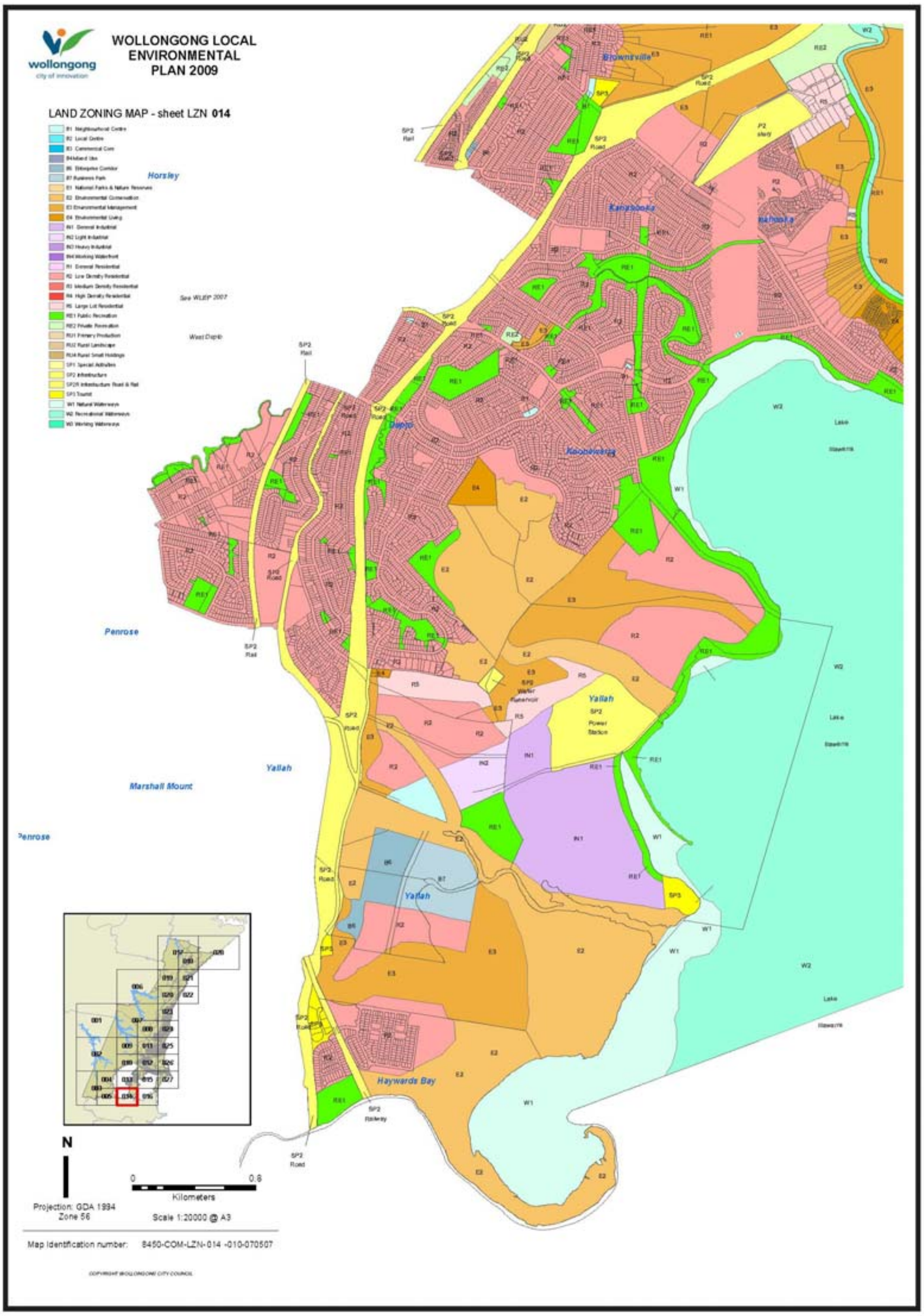
7.5. Impact of Proposed Land Zonings on the Assessed Power Station Risks and Summary of Results

The current land zoning surrounding the power station site is Special Uses (5a). It is proposed to rezone a number of areas surrounding the power station site to enable development of the area to proceed. A copy of the rezoning draft Local Environmental Plan has been included at **Figure 7-1**. **Figure 7-2** shows the location of the power station site in relation to the buffer zones surrounding the facility.

The assessment conducted in the above study has assessed the impacts to the various proposed land zonings surrounding the Tallawarra Power Station, including residential risks and industrial risks.

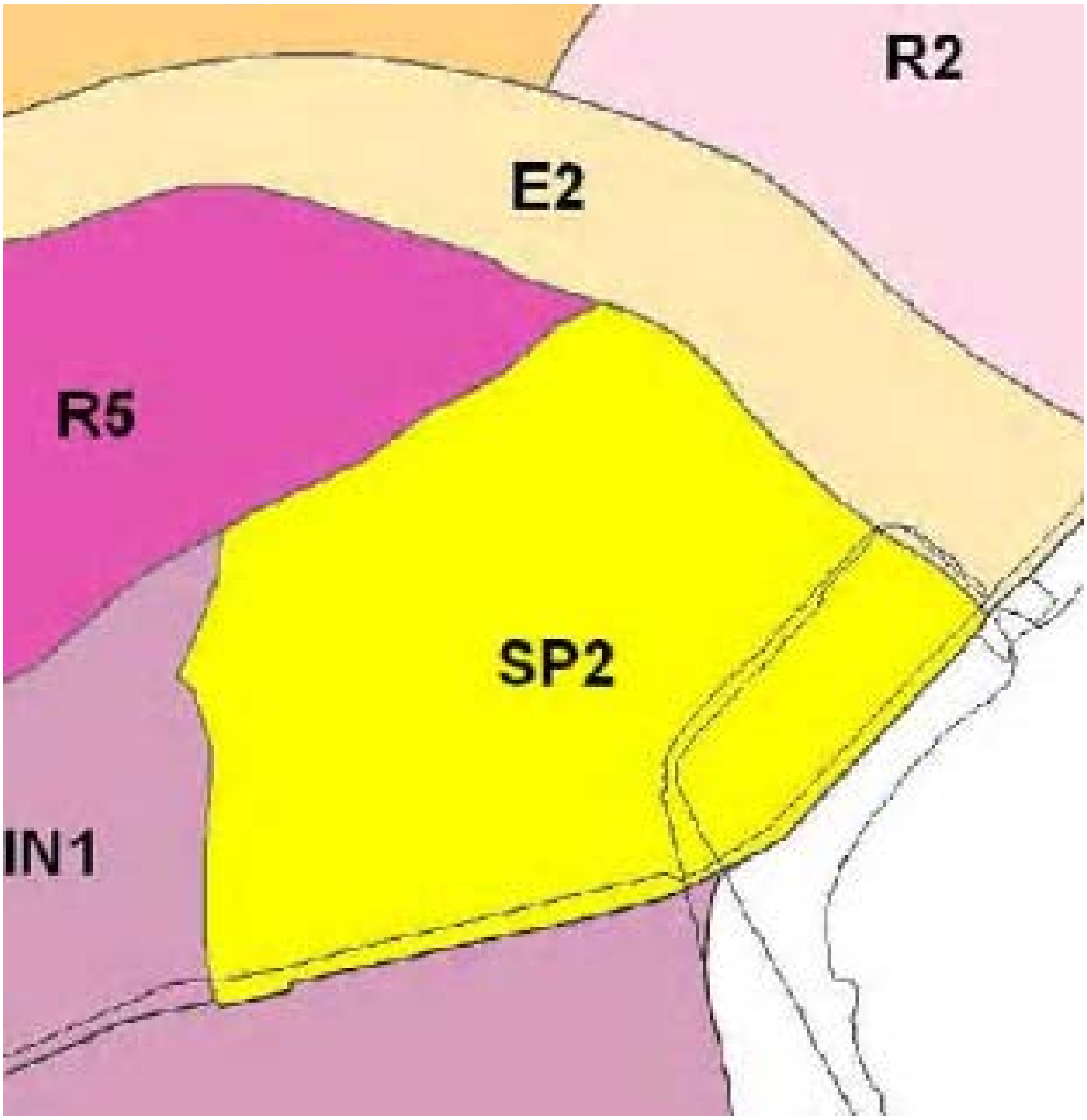
The study identified that the risks associated with the operation of the proposed power station did not exceed the published risk criteria in HIPAP No.4 (DIPNR 1992c). Hence, the facility may be classified as potentially hazardous and not actually hazardous within the definitions detailed in State Environmental Planning Policy No.33, “Hazardous and Offensive Developments”. Therefore the proposed power station extension (Stage B) would be permitted within the land zoning indicated in **Figure 7-1**.

- **Figure 7-1 Proposed land zoning - land surrounding the Tallawarra power station**



Extract from draft Wollongong Local Environmental Plan land zoning maps

Figure 7-2 Location of the Tallawarra power station in zone SP2



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Appendix A Hazard Identification Table

Site Area	Hazard Cause	Hazard Consequence	Proposed/Inherent Safeguard
Gas Fitting line	External interference Construction error, corrosion, earthquake, subsidence	Leak/rupture, ignition, jet fire, flash, explosion	▪ pipeline marker signs to be installed at regular intervals) ▪ pressure testing of fitting line after construction ▪ external paint system corrosion protection ▪ land is flat with no subsidence potential ▪ fitting line is installed in a pipe rack of substantial construction and remote from through traffic ▪ site work using mechanical equipment will be subject to a permit system and supervision.
Turbine Enclosure	Gas fitting line joint or pipe failure	Leak/rupture, ignition, jet fire, explosion	▪ gas detection within the enclosure ▪ automatic isolation valve located at gas entry point to the enclosure (linked to gas detection to operate at 50% LEL) ▪ enclosure is vented with fans ▪ alarms linked to gas detection ▪ fire detection installed in the enclosure (linked to fire fighting system) ▪ fire hydrants, hose reels and extinguishers available on site ▪ inert gas fire suppression installed in the gas turbine enclosure ▪ site is fully staffed during all operational periods (i.e. no fuel in the turbine when site is unstaffed)
Turbine Enclosure	Oil tank corrosion, valve failure, oil pipe failure	Leak of oil into the enclosure Spray of oil onto hot components resulting in spray fire	▪ enclosure is bunded to contain oil spillage ▪ oil pump is fitted with pressure relief valve ▪ oil lines are separated from hot parts of the gas turbine ▪ oil lines are stronger than maximum pressure of the system ▪ fire detection installed in the enclosure (linked to fire fighting system) ▪ site is fully staffed during all operational periods (i.e. oil system will not be in operation when site is unstaffed) ▪ inert gas fire suppression installed in the gas turbine enclosure ▪ fire hydrants, hose reels and extinguishers available on site
Turbine Enclosure	Diesel fuel pipeline joint or pipe failure	Leak of diesel into the enclosure Spray of diesel onto hot components resulting in spray fire	▪ enclosure is bunded to contain diesel spillage ▪ pipelines are separated from hot sections of the turbine ▪ pipelines are stronger than maximum pressure of the system ▪ fire hydrants, hose reels and extinguishers available on site ▪ fire detection installed in the enclosure (linked to fire fighting system) ▪ inert gas fire suppression installed in the gas turbine enclosure ▪ site is fully staffed during all operational periods (i.e. no fuel in the turbine

Site Area	Hazard Cause	Hazard Consequence	Proposed/Inherent Safeguard
			when site is unstaffed)
Diesel Storage	Tank, pipeline, pump leak	Spill of diesel fuel in the area surrounding the tank, pump or pipework, ignition, pool fire Release of diesel directly to ground from underground pipeline	■ diesel tank is bunded to contain 100% of stored liquid ■ pumps are installed in bunded area ■ diesel tank is separated from the remaining site buildings ■ fuel system is pressure tested prior to use (virtually eliminating leak potential ■ underground pipeline is corrosion protected and regularly pressure tested ■ fire hydrants, hose reels and extinguishers are available throughout the site ■ diesel storage area is regularly inspected as part of the site PM
Diesel Storage	Equipment failure (e.g. flexible hose) during fuel transfer to the tank (i.e. tanker delivery) Tanker drives away whilst still connected to the fill point	Spill of diesel fuel in the area surrounding the tanker transfer point, ignition, pool fire	■ diesel fuel transfer area is bunded ■ operator/driver is in attendance during the full transfer operation ■ fire hydrants, hose reels and extinguishers are available throughout the site ■ flexible hoses used for transfer are regularly inspected and pressure tested (6 monthly) ■ emergency shutdown valves installed on delivery tanker ■ driveaway protection provided on the tankers (i.e. pull down bar covering valve connection point applies truck brakes)
Transformers	Transformer component failure	Leak of oil from transformer joint or pipe, low oil level in transformer, winding failure, explosion, pool fire in oil spill under transformer	■ oil level alarm and transformer shut down system installed on all transformers ■ all transformers are bunded to contain full contents of oil in transformer ■ transformer oil is regularly inspected and tested to ensure oil characteristics are at optimum levels ■ transformer temperature is monitored during all operations ■ site is fully staffed during periods when transformers are in use (i.e. transformers are not used unless site is staffed) ■ fire hydrants, hose reels and extinguishers are available throughout the site
HV Switchyard	High voltage equipment failure	Release of SF6 gas, potential impact to people and the environment	■ SF6 is: ■ Non-poisonous ■ Non-toxic ■ Non-flammable ■ Non-reactive (chemically) ■ SF6 containing equipment will be regularly tested to monitor gas content ■ Relatively small quantities of SF6 gas held in equipment ■ Negligible impacts- Incident not carried forward for further analysis.
HV Switchyard	Minor oil containing equipment (e.g. transformers)	Leak of oil from equipment joint or pipe, low oil level in equipment, winding failure,	■ Note: minor equipment installed in the switchyard will have lower impact that scenarios carried forward for main transformers. Hence, scenarios and impact distances for main transformers also cover smaller equipment within

Site Area	Hazard Cause	Hazard Consequence	Proposed/Inherent Safeguard
		explosion, pool fire in oil spill under equipment	the switchyard. ▪ Where no offsite impact is assessed for main transformers, there ▪ will be no offsite impact from incidents in smaller equipment. ▪ Incident not carried forward for further analysis.
HV Switchyard	Fault in high voltage equipment resulting in discharge to the environment	Potential for high voltage contact between equipment and people	▪ Switchyard secured with 1.8m chainwire fence ▪ Separation distances between HV equipment and fence eliminated potential for HV arcs at the fence line ▪ Equipment is earthed, with earth leakage circuit breakers ▪ HV equipment will not operate without personnel in attendance at site (i.e. security) ▪ Negligible impact at site boundary, incident not carried forward for further analysis.

Appendix B Consequence analysis

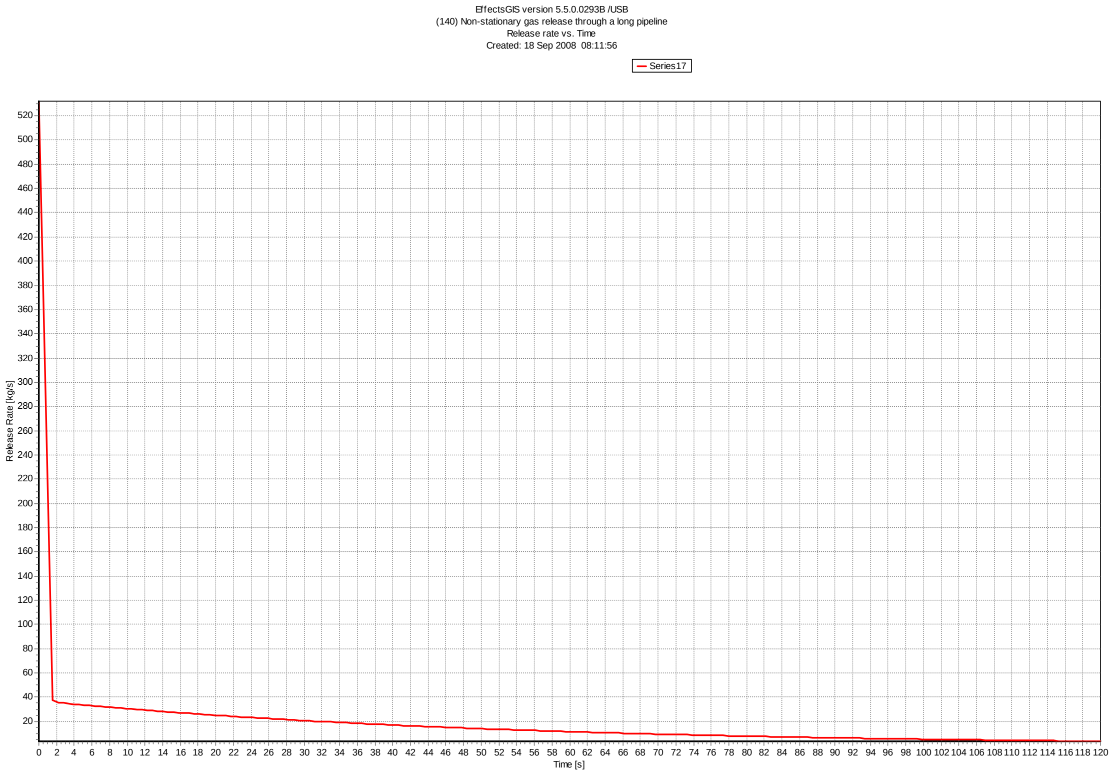
B.1 Gas Fitting line Consequence Analysis

A review of the hazard identification section indicates that the only gas fitting line incidents carried forward for further analysis are related to external impact and the potential for fitting line breach from mobile equipment (e.g. cranes, vehicles, etc.) striking the fitting line. It is noted that the fitting line is manufactured from X42 grade steel and that the pressure is about 5,300kPa or 53bar. Hence, propagation of a breach (i.e. hole created by an external impact) would not occur (SKM & Agility Communication 2005) at this pressure using “X” grade steel pipe.

Based on the above information, an external impact from mobile equipment (e.g. crane, vehicles, etc.) on a steel fitting line, with diameter 273mm and wall thickness 12.7mm, would cause fitting line rupture. Hence, to determine the leak rate from a 273mm hole in the fitting line (i.e. rupture), the EFFECTS© model was used. EFFECTS© is a series of loss estimation programs developed by the TNO Organisation in the Netherlands (TNO Safety Software 2003). In the event of a rupture in the fitting line, the release would commence with a significant surge of gas, reducing with time as the flow in the fitting line was restricted as a result of flow friction, etc. The depressuring flow from a 1km pipeline for example is shown in **Graph B1**. It can be seen from this graph that the flow commences with a high flow rate diminishing to a relatively low rate after 10 minutes.

It is noted that the gas supply to the site enters via an isolation and metering station, where a number of manual and automatic isolation valves are installed. In the event of a major leak (i.e. rupture), the rapid de-pressuring would be detected and the isolation valve closed automatically. This would isolate the flow of gas to the leak resulting in extinguishing of the fire due to lack of fuel source.

- **Graph B1 Depressuring flow rate from a guillotine fracture of gas supply fitting line to the gas turbine power station**



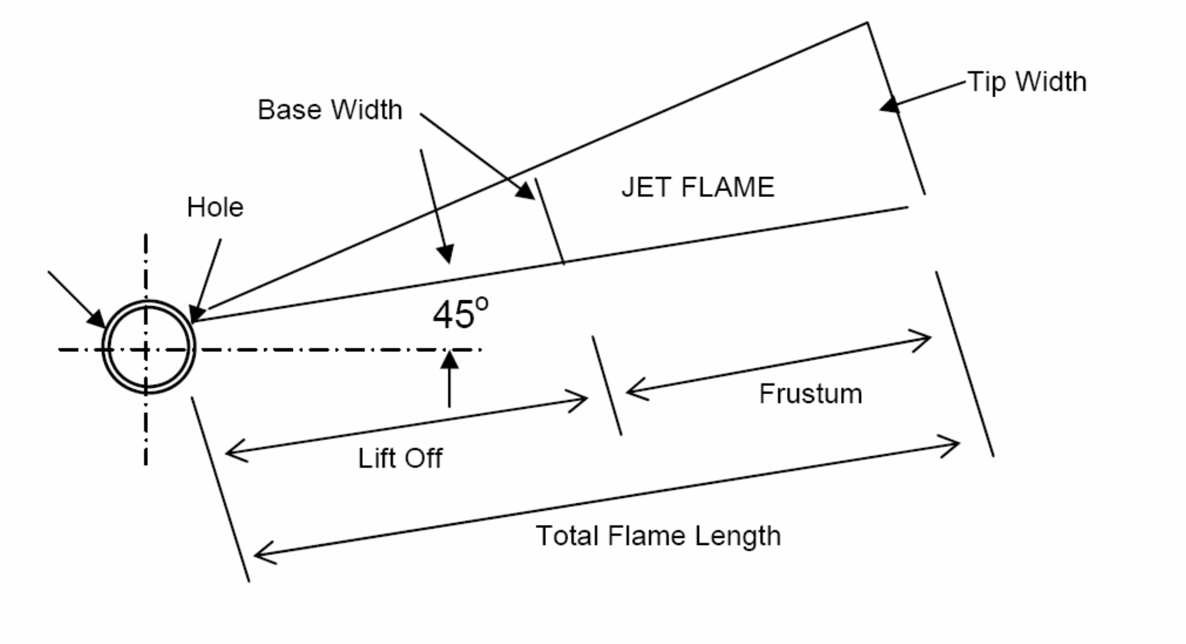
In the event of immediate ignition, the release would burn as a jet fire in the form shown in **Figure B1**. Much research has been conducted on the shape of jet fires, the most appropriate modelling shape being the frustum of a cone (Lees, F.P. 2001). An analysis of the fire shape and impact was performed using the EFFECTS© model, the results of the analysis are summarised in **Table B1**. A horizontal release will be directed upwards at an angle of about 45°. The EFFECTS© model has therefore used an angle of 45° for assessment of impacts to the surrounding areas.

Noting that the flow rate is constantly changing, due to de-pressuring, the flow rate used in the analysis of the jet fire has been selected based on the impact criteria published in HIPAP No.4 (DIPNR 1992b). HIPAP No.4 indicates that people impacted by more than 4.7kW/m^2 for over 30 seconds would feel pain and therefore need to move from the area. An average value of 30kg/sec has therefore been used, which is conservative, as the majority of gas has been released within the first few seconds of the incident.

- **Table B1 Heat radiation impacts from fitting line incidents as a result of jet fire from an external impact breach**

Hole Diameter (m)	Rupture (273mm)
Jet Fire Length-Total (m)	59.13
Width of Flame at End (m)	15.96
Width of Flame at Base (m)	2.26
Flame Lift Off (m)	10.9
Angle of Flame from Horizontal	45^o
Heat Radiation Level (kW/m^2)	Distance (m)
35	52.5
23	54.5
15	56
12.5	57
8	59
4.7	61
2	68

- **Figure B1 Jet flame schematic**



In the event a gas release from a hole does not immediately ignite, the gas will escape from the fitting line and be released as a gas jet, dispersing in the area surrounding the fitting line. It is noted that the fitting line will be installed in an easement, well clear of surrounding areas. The easement will not contain any structures that could confine the gas and, hence, in the event of an ignition, explosion is not likely in this area (Kletz, T 2006). The more likely scenario, in the event of an ignition, is a flash fire, whereby the gas cloud developed as a result of the release will burn rapidly but without deflagration (explosion).

A rupture of the fitting line in the easement will see a significant quantity of gas released, resulting a gas cloud of many tonnes. This will extend well beyond the easement boundary. Hence, ignition of the cloud would result in flash fire outside the confines of the fitting line easement.

Notwithstanding the large quantity of gas released, it is noted that the gas is considerably lighter than air and releases would rise and disperse above the plant.

B.2 Gas Leak into the Turbine Enclosure

In the event a gas leak occurs within the gas turbine enclosure, under normal circumstances the enclosure ventilation fan would extract the gas and disperse it externally. However, in the event the ventilation fan is shut down or in a failed condition, the gas would build up in the enclosure. Under these circumstances the gas will eventually reach the lower flammable limit and if ignited a gas explosion would occur. This explosion would result in destruction of the gas turbine enclosure and blast impact towards the site boundary.

To estimate the magnitude of the blast wave the TNT equivalence method was used. This method estimated the quantity of gas within an explosive cloud and equates the mass of gas to an equivalent mass of TNT. Empirical analysis can then be performed to estimate the blast pressure at specific distances from the blast centre.

To estimate the quantity of gas at LEL in the gas turbine enclosure, the volume of the enclosure is first calculated. The gas turbine enclosure dimensions have been assumed as (final designs have not yet been selected): 20m long x 4.2m wide x 4.4m high. Whilst the volume of the enclosure can be calculated as: 20x4.2x4.4 = 369.6m^3, the enclosure is fitted with equipment and the gas turbine unit itself. This reduces the free volume in the enclosure to below 50%. However, for this analysis a free volume of 50% has been assumed. Hence, the volume of gas (at LEL) that would explode if ignited is 369.6/2 = 184.8m^3.

The mass of methane, at LEL, within 184.8m^3 of gas is calculated as follows:

1 mole of gas is contained within each 22.4L. Hence, for 184,800 of gas the number of moles = 184,800/22.4 = 8,250 mole

At LEL there is a 5% mixture of methane gas in air. Hence, the total number of mole of methane = 8,250 x 0.05 = 412.5 mole. The molecular weight of methane is 16. Hence, the total mass of methane in the enclosure is 6,600kg.

The equivalent mass of TNT is calculated by:

$$W_{TNT} = \alpha\left(\frac{W.H_c}{H_{TNT}}\right)$$

Where: W = mass of fuel in the cloud (6,600 kg in the turbine enclosure)

H_c = heat of combustion of the fuel (38,000 kj/kg for methane)

H_{TNT} = TNT blast energy (5420 kj/kg)

α = explosion efficiency (0.04 for methane, Ref.15)

Hence,

W_{TNT} = 0.04 (6600x38000/5420) = 1,850kg TNT

Overpressure is now calculated using a scaled distance curve, based on actual distance from the blast and the TNT equivalent, this is given by:

$$z = \frac{R}{(W_{TNT})^{1/3}}$$

Where: R = distance from the blast (m)

W_{TNT} = kg equivalent of TNT

The closest gas turbine to the site boundary is Turbine No. 1, which is 135m from the north east boundary. Hence, for a value of R= 135 and W_{TNT} = 1,850 kg

$Z = 135/(1850)^{0.333} = 135/12.3 = 11$

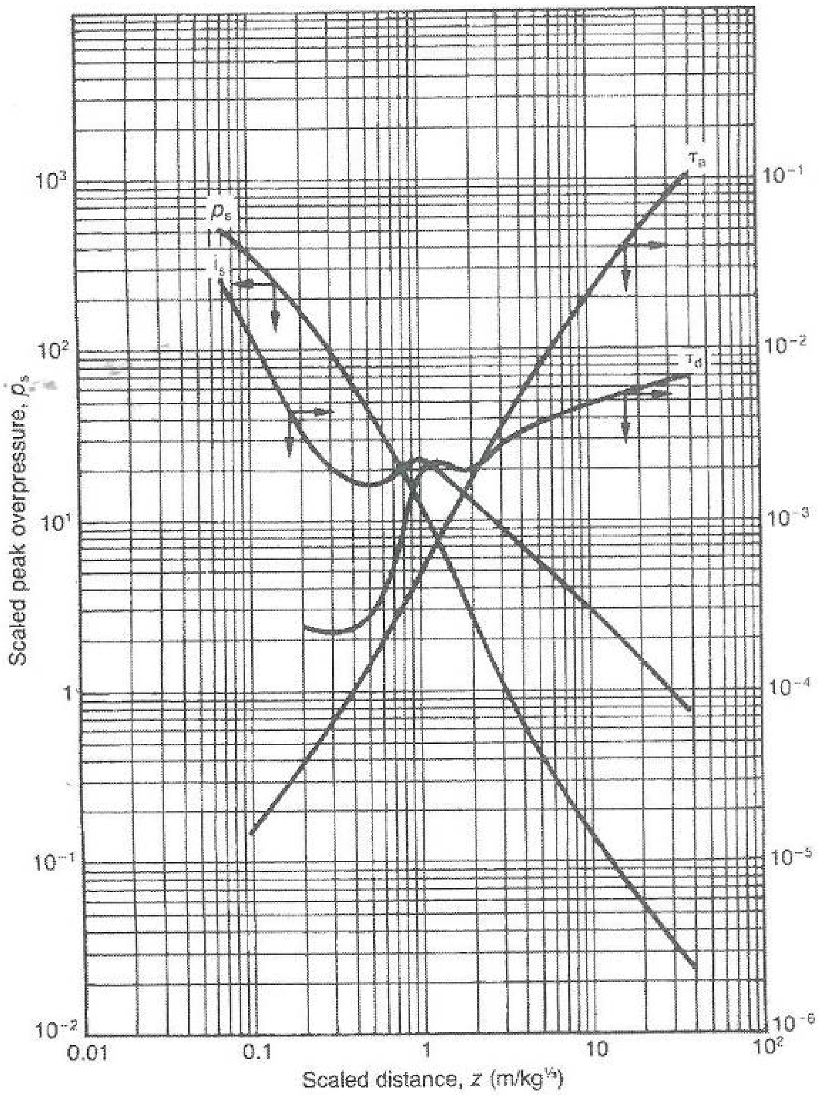
Z is now used to estimate the peak overpressure which can be read from a curve for scaled overpressure plots (see **Figure B2**). From **Figure B2** for a value of z = 11, the peak overpressure is read as 0.14bar or 14kPa.

The same analysis as that above was conducted to determine the distance to selected explosion overpressures. **Table B2** summarises the results of the analysis.

- **Table B2 Explosion overpressure versus distance for explosion in the gas turbine enclosure**

Explosion Overpressure (kPa)	Distance (m)
70	48
35	68
14	135
7	180.8

- **Figure B2 Scaled parameter plots for TNT explosions**



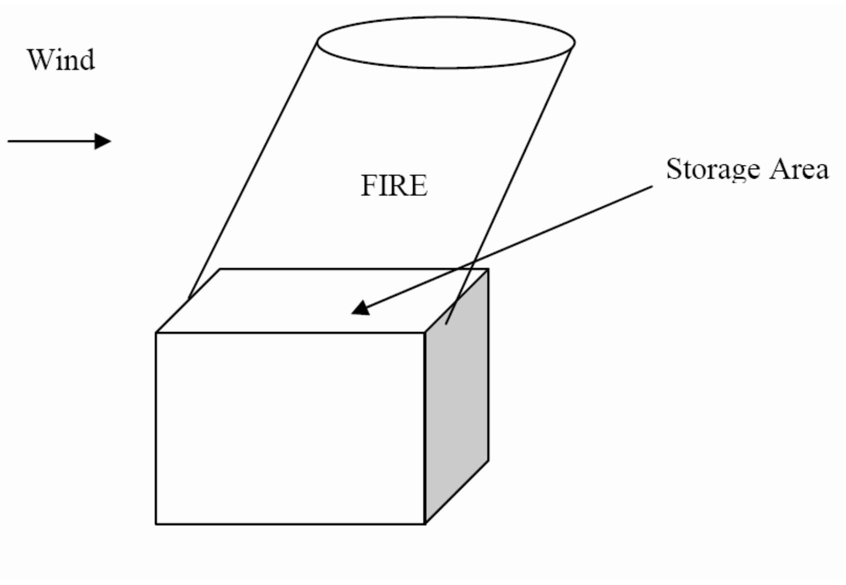
B.3 Oil Leak into the Gas Turbine Enclosure

In the unlikely event of a lubricating oil leak into the gas turbine enclosure, the leak would collect in the base of the enclosure, being contained by the enclosure bund. In the event of ignition of the leak, a pool fire would form resulting in eventual enclosure damage and flame exposure to areas outside the enclosure. The resultant heat radiation could impact offsite, hence, to estimate the heat radiation impact the following analysis was conducted.

The turbine enclosure is effectively split into two sections; half of the enclosure contains the gas turbine engine unit, the other half contains the generator, which also contains no oil or fuel. Hence, only half the enclosure requires bunding and the bund dimensions, used for estimating the pool fire, are 15m x 5m.

Figure B3 shows an illustration of a typical pool fire in a storage area. It can be seen from this illustration that the flame burns at the top of the storage and is affected by wind, causing the flame to tilt with the wind direction.

- **Figure B3 Example of a typical fire in a store**



The fire at the storage roof will act as a cylinder with the heat from the cylindrical flame radiating to the surrounding area. A number of mathematical models may be used for estimating the heat radiation impacts at various distances from the fire. The point source method is adequate for assessing impacts in the far field; however, a more effective approach is the view factor method, which uses the flame shape to determine the fraction of heat radiated from the flame to a target. The radiated heat is also reduced by the presence of water vapour and carbon dioxide in the air. The formula for estimating the heat radiation impact at a set distance is:

$$Q = E\ F\ \tau$$

Where: Q = incident heat flux at the receiver (kW/m^2)

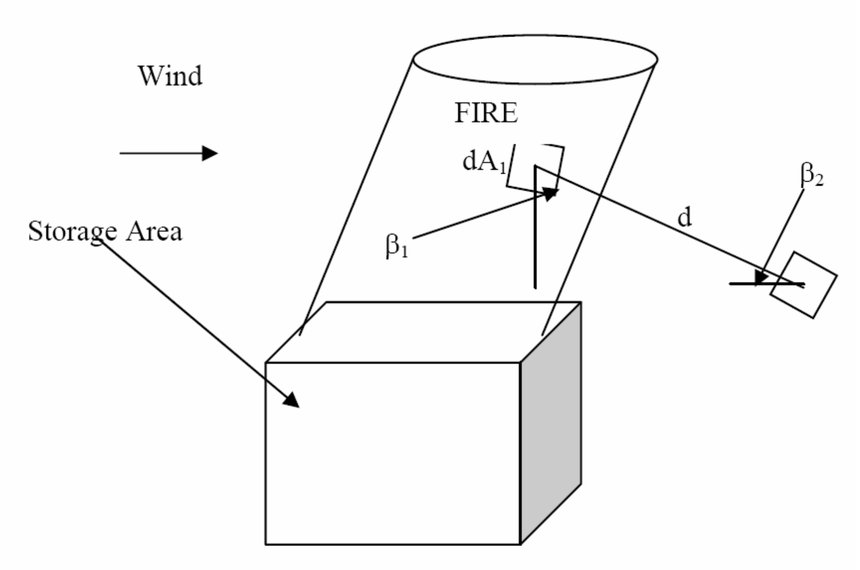
E = surface emissive power of the flame (kW/m^2)

F = view factor between the flame and the receiver

τ = atmospheric transmissivity

Figure B4 shows the heat radiation path for the fire. It can be seen from this figure that flame tilt and height above ground level will have impacts on the amount of heat flux received by the target.

- **Figure B4 Heat radiation impact on a target from a cylindrical flame**



The calculation of the view factor (F) in **Figure B3** depends upon the shape of the flame and the location of the flame to the receiver. F is calculated using an integral over the surface of the flame, S. The formula can be shown as:

$$F = \int\int_S \frac{\cos\beta_1 \cos\beta_2}{\pi d^2}$$

The above formula may be solved using the double integral or using a numerical integration method in spread sheet form. This is explained in **Section B3.1**.

B.3.1 Development of the Numerical Integration Method

B3.1.1 Introduction

The spreadsheet calculator (SSC) determines the radiation flux experienced at a “target” originating from a cylindrical fire. It is intended typically for fires of flammable liquids (Class 3) though it can be used with any material so long as the “emissivity” of the flame is known. This is the heat flux at the surface of the flame and is given in kilo Watts per square metre (kW/m^2). The other parameters needed are: diameter of the fire, height of the fire walls, distance to target, height of flame, tilt of flame caused by wind. It is assumed that the walls have some height although there is no reason not to use the calculator for pool fires at ground level by entering a zero height.

B3.1.2 Design Basis

The SSC is designed on the basis of finite elements. The fire is assumed to be in the shape of a cylinder of the same diameter as the equivalent pool diameter. The height of the fire can be calculated using the following formula:

$$L = 42D\left(\frac{m}{\rho_o (gD)^{0.5}}\right)^{0.61}$$ (Lees 2001)

where: L= mean flame height (m)

D= pool diameter (m)

ρ_o= ambient air density (typically 1.2 kg/m^3)

m= mass burning rate (kg/ m^2s) = 0.0667, based on 5mm/min burn down rate (Tweeddale 1993)

g= acceleration due to gravity (9.81 m/s^2)

Once the flame height is known, the surface of the cylinder can be divided into many separate plane surfaces. To do this, a plan view of the fire was drawn and the relevant distances and angles allocated. The plan view is for the target and the base of the fire in the same horizontal plane.

The angle “theta” is varied from zero to 90 degrees in intervals of 2.5 degrees. Zero deg. represents the straight line joining the centre of the tank to the target (x0, x1, x2) while 90 deg. is the point at the extreme left hand side of the fire base. In this way the fire surface is divided up into elements of the same angular displacement. Note the tangent to the circle in plan. This tangent lies at an angle, gamma, with the line joining the target to where the tangent touches the circle (x4). This angle varies from 90 deg at the closest distance between the tank and the target (x0) and gets progressively smaller as theta increases. As theta increases, the line x4 subtends an angle phi with x0. By similar triangles we see that the angle gamma is equal to 90-theta-phi. This angle is important because the sine of the angle give us the proportion of the projected area of the plane. When gamma is 90 deg, sin(gamma) is 1.0, meaning that the projected area is 100% of the actual area.

Before the value of theta reaches 90 degrees the line x4 becomes tangential to the circle. The fire cannot be seen from the rear and negative values appear in the view factors to reflect this. The SSC filters out all negative contributions.

For the simple case, where the fire is of unit height, the view factor of an element is simply given by the expression:

VF = ΔA. sin(gamma)/(π. x4. x4) .... Eq 1

where ΔA is the area of an individual element at ground level.

Note the denominator (π. x4. x4) is a term that describes the inverse square law for radiation assumed to be distributed evenly over the surface of a sphere.

Applying the above approach, we see the value of x4 increase as theta increase, and the value of sin(gamma) decreases as theta increase. This means that the contribution of the radiation from the edge of the circular fire drops off quite suddenly compared to a view normal to the fire. Note that the SSC adds up the separate contributions of Eq 1 for values of theta between zero until x4 makes a tangent to the circle.

It is now necessary to do two things: (i) to regard the actual fire as occurring on top of a fire wall (store) and (ii) to calculate and sum all of the view factors over the surface of the fire from its base to its top. The overall height of the flame is divided into 10 equal segments. The same geometric technique is used. The value of x4 is used as the base of the triangle and the height of the flame plus the tank, as the height. The hypotenuse is the distance from target to the face of the flame (called X4'). The angle of elevation to the element of the fire (alpha) is the arctangent of the height over the ground distance. From the cos(alpha) we get the projected area for radiation. Thus there is a new combined distance and an overall equation becomes:

VF = ΔA. sin(gamma).cos(alpha)/(π. x4'. x4') .... Eq 2

The SCC now turns three dimensional. The vertical axis represents the variation in theta from 0 to 90 deg representing half a projected circle. The horizontal axis represents increasing values of flame height in increments of 10%. The average of the extremes is used (e.g. if the fire were 10 m high then the first point would be the average of 0 and 1 i.e. 0.5 m), the next point would be 1.5 m and so on.

Thus the surface of the flame is divided into 360 equal area increments per half cylinder making 720 increments for the whole cylinder. Some of these go negative as described above and are not counted because they are not visible. Negative values are removed automatically.

The sum is taken of the View Factors in Eq.2. Actually the sum is taken without the ΔA term. This sum is then multiplied by ΔA which is constant. The value is then multiplied by 2 to give both sides of the cylinder. This is now the integral of the incremental view factors. It is dimensionless so when we multiply by the emissivity at the "face" of the flame, which occurs at the same diameter as the fire base (o pool), we get the radiation flux at the target.

B.3.2 Analysis Results

Prior to the development of the model, parameters were developed (e.g. flame height, SEP, wind tilt, etc.).

Tank Wall Height – 0m

Tank Diameter – 9.8m

Flame Height – 17.5m

$$L = 42D\left(\frac{m}{\rho_0 (gD)^{0.5}}\right)^{0.61}$$

where: L= mean flame height (m)

D= pool diameter (m)

ρo= ambient air density (typically 1.2 kg/ m^3)

m= mass burning rate (kg/ m^2s) = 0.0667, based on 5mm/min burn down rate (AS 2007)

g= acceleration due to gravity (9.81 m/s^2)

Using a diameter of 9.8m, the flame height is 17.5m.

Wind Tilt – a wind tilt of 30^o has been used for the analysis

Surface Emissive Power (SEP) – is a function of the fire magnitude (i.e. diameter and height), which governs the amount of heat at the surface of the fire. Larger fires tend to generate larger quantities of soot or smoke, which shields the more luminous components of the flame. Large diameter pool fires average an SEP of about 20kW/m^2. The average SEP of an 80m kerosene fire is about 10kW/m^2, suggesting the correlation is conservative (Tweeddale 1993).

The correlation of Mudan and Croce (Mudan & Croce 1988) give the following formula for calculating the SEP of a flame:

SEP = SEPm exp(-sD) + Es (1-exp(-sD))

Where: SEP = the total surface emissive power of the flame

SEPm = the maximum surface emissive power of luminous spots on a large hydrocarbon fuel flame (140kW/m^2)

SEPs = the surface emissive power of a smoky flame (20kW/m^2)

S = 0.12m-1 (an experimentally determined parameter)

D = diameter of the pool

Based on the above formula, the calculated SEP for the oil fire is 57kW/m^2.

Transmissivity – is the reduction in heat radiation due to the presence of water vapour and carbon dioxide in the atmosphere between the radiation source and the target. This can be calculated using the following formula (Tweeddale 1993):

Transmissivity = 1.006 - 0.01171(log10X(H_2O) - 0.02368($\log_{10}$X(H_2O)))^2 - 0.03188($\log_{10}$X(CO_2) + 0.001164($\log_{10}$X(CO_2)))^2

Where: X(H_2O) = (RH x L x Smm x 2.88651 x 102)/T

X(CO_2) = L x 273/T

RH = relative humidity

L = path length in metres

Smm = saturated water vapour pressure in mm mercury (= 17.535 @ 293K)

T = temperature in degrees Kelvin (293K)

The distance from the fire to the boundary of the proposed property (L) 135m, relative humidity is selected as 70% (0.7). Using these values and the values listed above, the transmissivity parameter is calculated to be 0.66.

B.3.3 Summary of Inputs to the SCC Model

Using the methodology presented in **Section 3.1** the following inputs have been developed for the heat radiation model.

Fire Diameter	9.8m
Fire height	17.5m
Flame tilt	30 degrees
SEP	57kW/m^2
Transmissivity	0.66(at site boundary, 30m)

B.3.4 Consequence Analysis (SCC Model Results)

The SCC model was entered into a Microsoft Excel spread sheet and the data above input to the model. The heat radiation at the site boundary (135m) was estimated to be 0.11kW/m^2. The SCC was run for varying heat radiation levels to determine the distance to impacts as a result of the tank fire. **Table B3** summarises the results of the SCC analysis

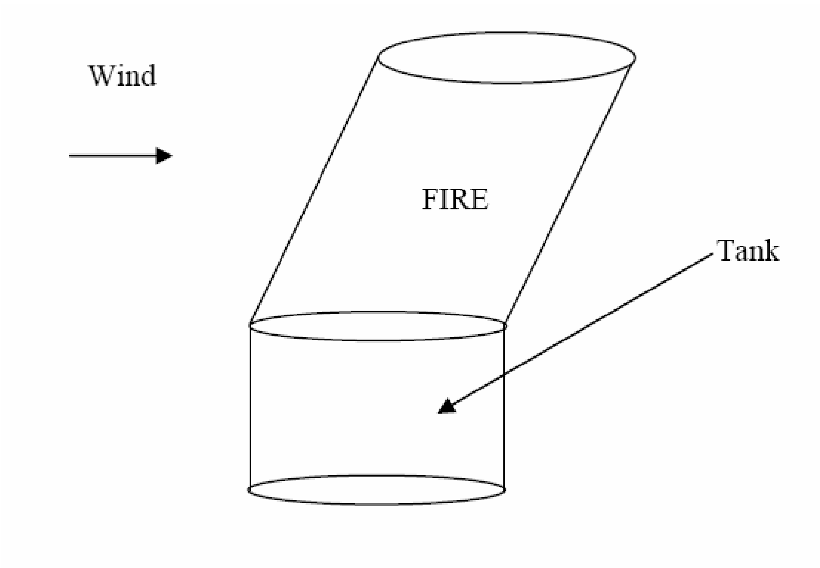
- **Table B3 Heat radiation impact at selection distances from a gas turbine pool fire incident**

Heat Radiation Impact (kW/m^2)	Distance (m)
35	12.6
23	14.3
15	16.5
12.5	17.5
8	20.7
4.7	25.5
2	37

B.4 Diesel Fuel Tank Storage Fire (OCGT only)

In the unlikely event an ignition occurs in the roof of the tank, a tank roof fire would occur. Eventual tank roof collapse would lead to fire exposure and heat radiation to the areas surrounding the tank. The tank diameter is 11m and the tank height is 10.5m. Hence, a tank roof fire would occur at 10.5m height and would be 11m diameter. **Figure B5** shows an illustration of a typical pool fire in a storage area. It can be seen from this illustration that the flame burns at the top of the storage and is affected by wind, causing the flame to tilt with the wind direction.

▪ **Figure B5 Typical fire in a store**



The fire at the storage roof will act as a cylinder with the heat from the cylindrical flame radiating to the surrounding area. The same mathematical model used for the roof fire can also be used for the tank fire (SSC).

B.4.1 Model Inputs

Tank Wall Height – 11.5m

Tank Diameter – 11m

Flame Height: - 19m

$$L = 42D\left(\frac{m}{\rho_0 (gD)^{0.5}}\right)^{0.61}$$

where: L= mean flame height (m)

D= pool diameter (m)

ρo= ambient air density (typically 1.2 kg/ m^3)

m= mass burning rate (kg/ m^2s) = 0.0667, based on 5mm/min burn down rate (AS 2007)

g= acceleration due to gravity (9.81 m/s^2)

Using a diameter of 11m, the flame height is 19m.

Wind Tilt – a wind tilt of 30^o has been used for the analysis

Surface Emissive Power (SEP) –Based on the formula used in the previous calculations (Section B3.2), the calculated SEP for the diesel fuel tank fire is 52kW/m^2.

Transmissivity – Using the previous formula for calculating transmissivity (Section B3.2), and using the distance from the fire to the boundary of the proposed property (L) 135m, relative humidity is selected as 70% (0.7). Using these values and the values listed above, the transmissivity parameter is calculated to be 0.66.

B.4.2 Summary of Inputs to the SSC Model

Using the methodology presented in **Section 3.1** the following inputs have been developed for the heat radiation model.

Tank height -	11.5m
Fire Diameter	12.5m
Fire height	20.8m
Flame tilt	30 degrees
SEP	47kW/m^2
Transmissivity	0.66 (at site boundary, 135m)

B.4.3 Consequence Analysis (SCC Model Results)

The SSC model was entered into a Microsoft Excel spread sheet and the data above input to the model. The heat radiation at the site boundary (135m) was estimated to be 0.14kW/m^2. The SSC was run for varying heat radiation levels to determine the distance to impacts as a result of the tank fire. **Table B4** summarises the results of the SCC analysis.

- **Table B4 Heat radiation impact at selected distances from a diesel fuel tank fire incident**

Heat Radiation Impact (kW/m^2)	Distance from Tank (m)
35	6.9
23	10
15	13.5

12.5	15.2
10	17.4
8	19.5
4.7	26
2.0	40

B.5 Diesel Fuel Tank Bund Fire (OCGT only)

In the event a diesel fuel spill occurs, in the bund, and the spill is ignited, a bund fire will result. The bund dimensions of 25m x 25m have been assumed and a fire in this area would behave as a pool fire of diesel fuel. The SCC model was run using various distances from the flame. The results of the analysis are summarised in **Table B5**.

B.5.1 Summary of Inputs to the SCC Model

Using the methodology presented in **Section 3.1** the following inputs have been developed for the heat radiation model.

Fire Diameter 28.2m

Fire height 36.57m

Flame tilt 30 degrees

SEP 24kW/m^2

Transmissivity 0.66(at site boundary, 135m)

B.5.2 Consequence Analysis (SSC Model Results)

The SSC model was entered into a Microsoft Excel spread sheet and the data above input to the model. The heat radiation at the site boundary (135m) was estimated to be 0.28kW/m^2. The SSC was run for varying heat radiation levels to determine the distance to impacts as a result of the tank fire. **Table B5** summarises the results of the SSC analysis.

- **Table B5 Heat radiation impact at selected distances from a diesel fuel tank bund fire incident**

Heat Radiation Impact (kW/m^2)	Distance (m)
23	24.5
15	27.3
12.5	28.8
10	31
8	33.5
4.7	40.5
2	57

B.6 Diesel Fuel Unloading Area Fire (OCGT only)

Diesel fuel will be delivered to site by 55,000kL tankers. The fuel will be transferred by tanker mounted, flexible hose and fixed pipework to the diesel fuel tank. A dedicated unloading area will be constructed adjacent to the diesel fuel tank. Fuel will be unloaded by the tanker driver, who will be in attendance throughout the whole transfer operation. The tanker is fitted with emergency shut off valves that can be isolated by the driver in the event of leak or spill. The tanker is also fitted with driveaway protection to prevent the driver from leaving the site without first disconnecting the transfer hoses.

The most likely leak would occur from a split or failed hose. In this event the leak would be immediately isolated by the driver, using the emergency shut off devices on the tanker. However, once the fuel transfer has been isolated, the remaining fuel in the pipelines and transfer hoses would still leak from the split resulting in the fuel pooling in the transfer area. The fuel would be retained by the transfer area bund, which is located under the tanker and has assumed dimensions 21m long x 11m wide.

Assuming the fuel leaking from the hose and pipework spreads into this area, and covers the bund, the equivalent bund diameter is:

$21 \text{x} 11 = \pi/4 \text{ x } D^2$

D = 17m

Based on a pool diameter of 17m, the SCC model was run for pool fire. The results of the analysis are summarised in **Table B6**.

B.6.1 Summary of Inputs to the SSC Model

Using the methodology presented in **Section 3.1** the following inputs have been developed for the heat radiation model.

Fire Diameter	17m
Fire height	25.7m
Flame tilt	30 degrees
SEP	35.6kW/m^2
Transmissivity	0.66(at site boundary, 135m)

B.6.2 Consequence Analysis (SSC Model Results)

The SCC model was entered into a Microsoft Excel spread sheet and the data above input to the model. The heat radiation at the site boundary (135m) was estimated to be 0.12kW/m^2. The SCC was run for varying heat radiation levels to determine the distance to impacts as a result of the tank fire. **Table B6** summarises the results of the SCC analysis.

- **Table B6 Heat radiation impact at selected distances from a diesel fuel unloading area fire incident**

Heat Radiation Impact (kW/m^2)	Distance (m)
35	16.8
23	18.3
15	21.2
12.5	22.5
10	24.3
8	26.3
4.7	32.2
2	46

B.7 Diesel Leak into the Gas Turbine Enclosure (OCGT only)

In the event of a diesel fuel leak into the gas turbine enclosure, the leak would collect in the base of the enclosure, being contained by the enclosure bund. In the event of ignition of the leak, a pool fire would form resulting in eventual enclosure damage and flame exposure to areas outside the enclosure. The resultant heat radiation could impact offsite, hence, to estimate the heat radiation impact the following analysis was conducted.

The turbine enclosure is effectively split into two sections; half of the enclosure contains the gas turbine engine unit, the other half contains the generator, which also contains no oil or fuel. Hence, only half the enclosure requires bunding and the bund dimensions, used for estimating the pool fire, are 15m x 5m.

The equivalent diameter of the bund is estimated by:

Bund Area (15x5) = $\pi/4 \times D^2$

$D = (75 \times 4/\pi)^{0.5} = 9.8m$

The SSC pool fire model was used to estimate the heat radiation impact for pool fires in the turbine enclosure. The results of the analysis, using a pool diameter of 9.8m are summarised in **Table B7**.

B.7.1 Summary of Inputs to the SSC Model

Using the methodology presented in **Section 3.1** the following inputs have been developed for the heat radiation model.

Fire Diameter	9.8m
Fire height	17.5m
Flame tilt	30 degrees
SEP	57kW/m^2
Transmissivity	0.66 (at site boundary, 135m)

B.7.2 Consequence Analysis (SCC Model Results)

The SCC model was entered into a Microsoft Excel spread sheet and the data above input to the model. The heat radiation at the site boundary (135m) was estimated to be 0.11kW/m^2. The SCC was run for varying heat radiation levels to determine the distance to impacts as a result of the tank fire. **Table B7** summarises the results of the SCC analysis.

- **Table B7 Heat radiation impact at selected distances from a gas turbine pool fire incident**

Heat Radiation Impact (kW/m^2)	Distance (m)
28.08	12.6
18.24	14.3
11.94	16.5
10.15	17.5
6.55	20.7

3.94	25.5
2.69	30
1.67	37

B.8 Transformer Leak and Fire

In the event of a transformer leak the oil level in the transformer will gradually fall until the windings are exposed and sparking occurs resulting in transformer fire. The fire would also grow into the oil leaked into the bund, resulting in a bund fire. Whilst switches are installed on each transformer (i.e. low level oil switch isolating power to the transformer) failure of the switch may result in oil leak continuing, leading to ignition and fire.

The transformer bunds are 16m long x 13m wide. Bund equivalent diameter is:

$LxB\ (16x13) = \pi/4 \times D^2$

$D = (208 \times 4/\pi)^{0.5} = 16.3m$

The SCC pool fire model was used to estimate the heat radiation impact for pool fires in the transformer bund. The results of the analysis, using a pool diameter of 16.3m are summarised in **Table B8**.

B.8.1 Summary of Inputs to the SCC Model

Using the methodology presented in **Section 3.1** the following inputs have been developed for the heat radiation model.

Fire Diameter 16.3m

Fire height 25m

Flame tilt 30 degrees

SEP $37kW/m^2$

Transmissivity 0.66(at site boundary, 135m)

B.8.2 Consequence Analysis (SCC Model Results)

The SCC model was entered into a Microsoft Excel spread sheet and the data above input to the model. The heat radiation at the site boundary (135m) was estimated to be $0.17kW/m^2$. The SCC was run for varying heat radiation levels to determine the distance to impacts as a result of the tank fire. **Table B8** summarises the results of the SCC analysis.

- **Table B8 Heat radiation impact at selected distances from a transformer pool fire incident**

Heat Radiation Impact (kW/m^2)	Distance (m)
35	16.5
23	18.3
15	20.8
12.5	22.1
4.7	31.8
2	45