15.1 Introduction

The Department of Planning's *Multi Level Risk Assessment Guidelines* provide a guide to the level of hazard assessment necessary for a development being considered. In accordance with these guidelines, and as part of the Environmental Assessment, a quantitative Preliminary Hazard Analysis (PHA) was prepared for the proposed Delta Electricity Gas Fired Turbine Facility at Marulan.

The following sections summarise the results of the PHA undertaken by Planager Risk Management Consulting for the Facility. The full report is presented in **Appendix H**.

The assessment has been carried out in accordance with the Department of Planning's Hazardous Industry Planning Advisory Paper (HIPAP) No 6 (*Guidelines for Hazard Analysis*) and HIPAP No 4 (*Risk Criteria for Land Use Planning*). These documents describe the methodology and the criteria to be used in PHAs for major "potentially hazardous" development.

In accordance with Department of Planning's HIPAP No. 3 *(Environmental Risk Impact Assessment Guidelines),* the safety assessment process would continue throughout the design, construction and commissioning the Facility to refine and update the outcome of the development approval / environmental risk process.

15.2 Methodology

The process for PHA follows a number of steps which provide assurances that risks imposed by a development upon surrounding land uses would be within acceptable limits and that this would continue to be the case throughout the life of the development.

The aims of the PHA are to:

- identify and analyse the hazards and risks associated with all processes involved with the handling and transporting of potentially hazardous material which form part of the Project;
- assess the findings against the risk criteria currently in use by Department of Planning; and
- identify opportunities for risk reduction, and make recommendations as appropriate.

The risk assessment has quantitatively determined the risk of fatality and injury to the public associated with the handling and processing of potentially hazardous material at the Facility.

The report assesses the risks from the following:

- Delta Electricity Facility;
- the effect of risk of the Delta Electricity Facility on the proposed EnergyAustralia Facility; and
- the effect of risk of the EnergyAustralia Facility on the proposed Delta Electricity Facility.

There are five stages in risk assessment, each of which is described below.

15.2.1 Stage 1 - Hazard Identification

The hazard identification includes a review of potential hazards associated with all dangerous and hazardous goods to be processed, used and handled at the Facility. The hazard identification includes a comprehensive identification of possible causes of potential incidents and their consequences to public safety and the environment, as well as an outline of the proposed operational and organisational safety controls required to mitigate the likelihood of the hazardous events from occurring.

The tasks involved in the hazard identification for the Facility included a review of all relevant data and information to highlight specific areas of potential concern and points of discussion, including drafting up of preliminary hazard identification word diagram. The hazard identification word diagram was then reviewed and completed in a workshop which included people with operational, engineering and risk assessment expertise. The review takes into account both random and systematic errors, and gives emphasis not only to technical requirements, but also to the management of the safety activities and the competence of people involved in them.

The final hazard identification word diagram is presented in **Appendix H**.

15.2.2 Stage 2 - Consequence and Effect Analysis

The consequences of identified hazards are assessed using current techniques for risk assessment. Well established and recognised correlations between exposure and effect on people are used to calculate impacts.

15.2.3 Stage 3 - Frequency Analysis

For incidents with significant effects, whether on people, property or the biophysical environment, the incident frequency is estimated based on historical data. A probabilistic approach to the failure of vessels and pipes is used to develop frequency data on potentially hazardous incidents.

15.2.4 Stage 4 - Quantitative Risk Analysis

The combination of the probability of an outcome, such as injury or death, combined with the frequency of an event gives the risk from the event. In order to assess the merit of the proposal, it is necessary to calculate the risk at a number of locations so that the overall impact can be assessed. The risk for each incident is calculated according to:

Risk = Consequence x Frequency

Total risk is obtained by adding together the results from the risk calculations for each incident, i.e. the total risk is the sum of the risk calculated for each scenario.

The results of the risk analysis are presented in three forms:

Individual Fatality Risk

Individual Fatality Risk is the likelihood (or frequency) of fatality to notional individuals at locations around the Facility, as a result of any of the postulated fire and explosion events. The units for individual risk are probability (of fatality) per million per year. Typically, the result of individual risk calculations is shown in the form of risk contours overlaid on a map of the development area.

Injury and irritation risk

Injury and irritation risk, i.e., the likelihood of injury to individuals at locations around the Facilities as a result of the same scenarios used to calculate individual fatality risk.

Societal risk

Societal risk takes into account the number of people exposed to risk. Whereas individual risk is concerned with the risk of fatality to a (notional) person at a particular location (person 'most at risk', i.e., outdoors), societal risk considers the likelihood of actual fatalities among any of the people exposed to the hazard. Societal risk is presented as so called *f-N curves*, showing the frequency of events (f) resulting in N or more fatalities. To determine societal risk, it is necessary to quantify the population within each zone of risk surrounding a facility. By combining the risk results with the population data, a societal risk curve can be produced.

The risk results are then assessed against the guidelines adopted by the Department of Planning.

15.2.5 Stage 5 - Risk reduction

Where possible, risk reduction measures are identified throughout the course of the study in the form of recommendations.

15.3 Risk Criteria

15.3.1 Individual Risk Criteria

The individual fatality risk is the probability of fatality to a person or the Facilities at a particular point. It is usually expressed as chances per million per year (pmpy). It is assumed that the person will be at the point of interest 24 hours per day for the whole year. By convention in NSW, no mitigation is allowed, i.e., any possible evasive action that could be taken by a person exposed to a hazardous event, e.g., by walking out of a toxic cloud or a heat radiation. The assessment of fatality, incident propagation and injury risk would include all components contributing to the total risk, e.g. fire and explosion.

The Department of Planning uses a set of guidelines on acceptable levels or individual risk which are in line with the criteria used elsewhere in the world. These guidelines are published in the Hazardous Industry Planning Advisory Paper No. 4: *Risk Criteria for Land Use Safety Planning*.

15.3.2 Societal Risk Criteria

Societal risk is concerned with the potential for an incident to coincide in time and space with a human population. Societal risk takes into account the potential for an incident to cause multiple fatalities. Therefore, two components are relevant, namely:

- the number of people exposed in an incident; and
- the frequency of exposing a particular number of people.

The societal risk criteria specify levels of societal risk which must not be exceeded by a particular activity. The same criteria are currently used for existing and new developments. Two societal risk criteria are used, defining acceptable and unacceptable levels of risk due to a particular activity. The criteria are represented on the societal risk (f-N) curve as two parallel lines. Three zones are thus defined:

1. Above the unacceptable/intolerable limit the societal risk is not acceptable whatever the perceived benefits of the development.

2. The area between the unacceptable and the acceptable limits is known as the ALARP (as low as reasonably possible) region. Risk reduction may be required for potential incidents in this area.

3. Below the acceptable limit, the societal risk level is negligible regardless of the perceived value of the activity.

15.4 Assessment of Potential Impacts – Delta Electricity Facility

This section address the hazards of the Delta Electricity Facility both Stage 1 and Stage 2.

15.4.1 Summary of Hazard Identification Process

The main hazard associated with the Delta Electricity Facility (both Stage 1 and Stage 2) is related to a leak of flammable natural gas.

This would generally only have the potential to cause injury or damage if there was ignition, which resulted in a fire or explosion incident. The factors involved are:

- the pipelines, vessel or equipment must fail in a particular mode causing a release. There are several possible causes of failure, with the main ones being corrosion and damage by external agencies;

- the released material must come into contact with a source of ignition. In some cases this may be heat or sparks generated by mechanical damage while in others, the possible ignition source could include non-flame proof equipment, vehicles, or flames some distance from the release;

- depending on the release conditions, including the mass of flammable material involved and how rapidly it ignited, the results may be a localised fire (for example a jet fire), a flash fire or an explosion of the vapour cloud formed through the release; and

- finally, for there to be a risk, people must be present within the harmful range (consequence distance) of the fire or explosion. How close the people are will determine whether any injuries or fatalities result. Environmental damage from gas fire incidents are generally associated with a failure to control fire water used.

Natural gas is a buoyant, flammable gas which is lighter than air (relative density of 0.6). On release into the open, the non-ignited gas tends to disperse rapidly at altitude. Ignition at the point of release is possible, in which case the gas would burn as a jet (or torch) flame. On release in an enclosed area (for example within the gas turbine housing) an explosion or a flash fire is possible.

The gas is non-toxic, posing only an asphyxiation hazard. Due to its buoyancy, any release of credible proportions from operations of this scale, in the open, would not present an asphyxiation hazard. With standard confined space entry procedures and appropriate security arrangements to prevent unauthorised access to the Facility, the risk associated with asphyxiation from natural gas should be minimal.

Locally, the pressure of the compressed gas may be hazardous in case of an uncontrolled release. These hazards, while of importance for people working at the site, do not have implications beyond the immediate location of the release unless the released gas is ignited. Therefore, the risk associated with non-ignited compressed gas does not form part of the scope of the present risk assessment. This potential risk would however need to be closely managed through job safety analysis (JSA) and/or other risk assessment practices used by management and operators of the facility (in accordance with NSW *Occupational Health and Safety Act 2000* and its associated legislation).

Other potential hazards are associated with the handling and use of distillate and other combustible liquids (i.e. the oils used for pumps, compressors, turbines, etc). These combustible materials are difficult to ignite and require heating and a significant source of energy. If ignited they would burn as a sooty pool fire.

The risk associated with the proposed minor storage of chlorine and anhydrous ammonia gases is related to the potential for loss of containment of a toxic gas and subsequent exposure to these gases. The effects of exposure to toxic materials on humans can range from discomfort (e.g., irritation to eyes or skin) to injury (e.g., damage to lungs or respiratory system) to fatality. Effects are generally classified as chronic or acute. An acute effect is a response that rapidly follows exposure (within seconds, minutes or hours). A chronic effect can result from prolonged exposure, or from a series of exposures over a period measured in days, months or years. Only acute exposure potentials are discussed in this PHA.

The key factors which determine exposure effects are:

- toxicity of material;
- concentration of material;
- duration of exposure;
- mode of exposure (eg. inhalation, ingestion, skin); and
- sensitivity of person exposed.

Chlorine (DG Class 2.3) is a greenish-yellow gas, 2.5 times heavier than air at ambient temperature and pressure. It is highly toxic, and acts as a respiratory irritant. It has a characteristic pungent odour that can be smelt at low concentrations (that do not constitute an acute hazard). Therefore the odour can act as a hazard warning. Chlorine is non-flammable, however is an oxidising agent and therefore supports combustion.

Ammonia (DG Class 2.3, subsidiary risk Class 8) is a colourless gas with a penetrating, pungent suffocating odour detectable at low concentrations (17 ppm). As it combines with the humidity in the air upon release it acts as a heavy gas at ambient temperature and pressure. Ammonia is flammable at a concentration between 15.5 % and 27 %.

A total of 20 hazards were identified for the Delta Electricity Facility, as listed in **Table 15-1**.

Table 15-1 Summary of Identified Hazards

Number	Hazardous Event Potential	Offsite Impact Potential
1	Leak of natural gas to atmosphere from gas pipes at the Facility (outside the turbine enclosure)	Yes
2	Venting of gas from process	No
3	Explosion within gas piping or inside a vessel	No
4	Leak of natural gas to inside the turbine enclosure	Yes
5	Unburned fuel within the turbine	No
6	High pressure steam release	No
7	Loss of containment of distillate during unloading and storage	Yes
8	Loss of containment of corrosive liquids	No
9	Loss of containment of toxic gas	Yes
10	Violent reaction between incompatible materials	No
11	Loss of containment of water treatment plant effluent	No
12	Fire at transformers	Yes
13	Flooding results in process upsets and damage to plant and equipment	Yes
14	Land subsidence, earthquake or mining activity results in plant damage	Yes
15	Aircraft crash results in process upsets, potential damage to process / piping / storage facilities resulting in hazardous releases	Yes
16	Damage to plant through terrorism / vandalism / unlawful entry to Facility / sabotage	Yes
17	Neighbouring fire (from neighbouring EnergyAustralia Facility or bush / grass fire)	Yes
18	Storm damage	Yes
19	Incident during maintenance and repair work	Yes
20	Transport of potentially hazardous material to and from the Facility (diesel, oils, corrosives)	Yes

The full PHA presents a hazard identification word diagram summarising the potential hazardous incidents and their associated mitigating features. This assessment determined that seven events had no potential for offsite effects. The other thirteen hazards were assessed in more detail. The detailed risk assessment is presented in **Appendix H** and summarised below.

Consequence Analysis

This initial outflow rates estimated for natural gas releases are shown in **Table 15-2**.

Table 15-2 Release Rates

Release rate (kg/s)	Hole Size					
	Small leak (3mm)	Flange leak (13 mm)	Interme-diate leak (25 mm)	Major leak (80 mm)	Massive leak (100 mm)	Full bore (guillotine)
Upstream of the Pressure Regulator						
Instantaneous	0.08 kg/s	1.4 kg/s	5.3	54	84 kg/s	526 kg/s (first few seconds)
Downstream of the Pressure Regulator						
Instantaneous	0.03 kg/s	0.6 kg/s	2	22	34 kg/s	214 kg/s (first few seconds)

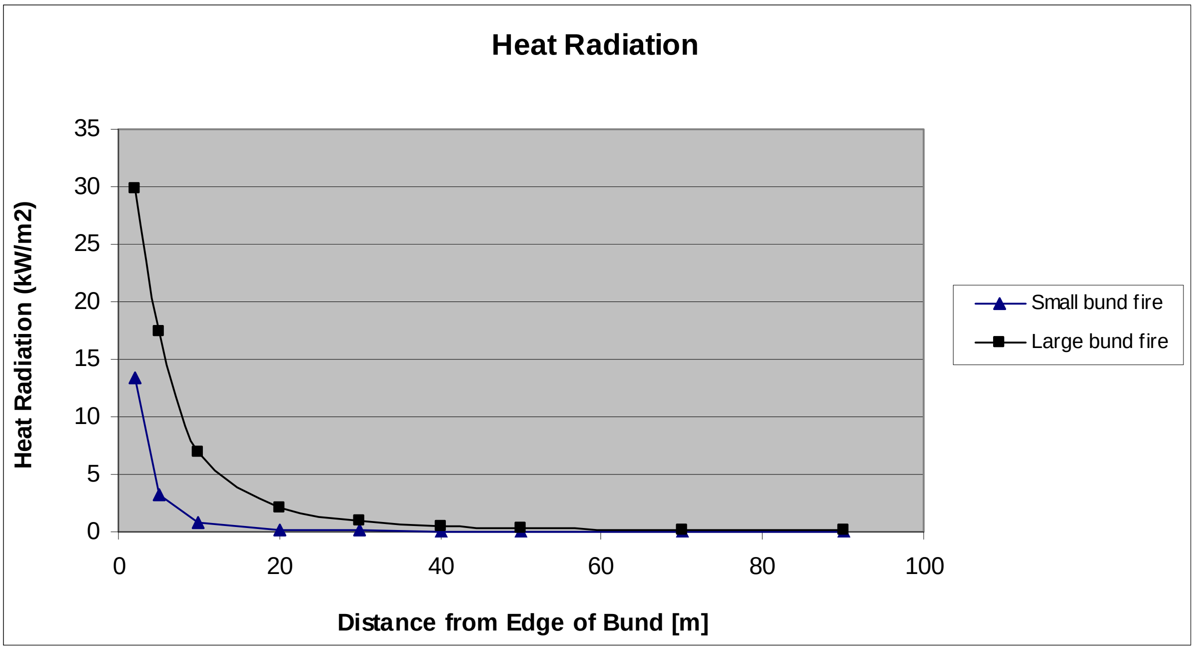
The distance from the source of the fire to the specified heat radiation for jet fire scenarios is listed in **Table 15-3**.

Table 15-3 Heat Radiation from Jet Fires

Hole size	Distance to Heat radiation (metres)		
	4.7 kW/m^2	12.5 kW/m^2	23.5 kW/m^2
Upstream of the Pressure Regulator			
Small leak (5 mm)	5	3	3
Intermediate leak (25 mm)	25	15	12
Massive leak (100 mm)	105	65	50
Full bore (guillotine)	260	160	115
Downstream of the Pressure Regulator			
Small leak (5 mm)	3	2	1.5
Intermediate leak (25 mm)	16	10	8
Massive leak (100 mm)	65	40	30
Full bore (guillotine)	165	100	75

The consequences of a distillate fire, as calculated using the Point Source method, are presented in **Figure 15-1** (with detailed calculation sheet is included in **Appendix H**). Two scenarios were investigated, namely a “small” and a “large” fire, covering 10 % and 100 % of the surface of the bund respectively (bund assumed to be 20 m^2).

Figure 15-1 Heat Radiation from Distillate Bund Fire



Frequency Analysis

The design of the Facility has not been finalised and in some cases, conservative assumptions relating to the design were made, including the length of pipe, number of flanges required, operating pressures used, etc.

The equipment failures and associated frequencies are presented in **Table 15-4**.

Table 15-4 Equipment Failures and Associated Frequencies

Type of Failure	Failure Rate (pmpy)
PIPELINES WITHIN FIXED PLANT (POWER PLANT)	
3 mm hole	9 / m
13 mm hole	3 / m
50 mm hole	0.3 / m
3 mm gasket (13 mm hole equivalent)	5 / joint
Guillotine fracture (full bore):	0.6 / m
< 50 mm	0.3 / m
> 50 mm but < 100 mm	0.1 / m
> 100 mm	
VESSELS	
6 mm hole	24
13 mm hole	6
25 mm hole	3
50 mm hole	3

15.4.2 Risk Assessment

Turbine Enclosure

The likelihood of a confined explosion inside the turbine enclosure was estimated taking into account a number of assumptions and recommendations.

With two enclosures, the total frequency of explosion inside turbine housing is:

$$F(\text{explosion in turbine housing}) = 1.45 \times 10^{-7} \text{ per year.}$$

This frequency is very low.

A confined explosion may generate high over pressures which could damage neighbouring equipment and gas turbines. It is however understood that the enclosures will be designed with explosions vents (or panels) which would blow out in case of a pressure event, thereby reducing the effect of the confinement. Further, the turbines at the neighbouring EnergyAustralia Facility will be separated from the Delta Electricity turbines by at least 100 m.

With proper design it is unlikely that an explosion at one turbine would have serious effect at a neighbouring turbine.

Recommendations are also made to ensure that the risk from an explosion at the turbine enclosure will be contained within the Facility boundary.

Diesel storage

The likelihood of a distillate fire at the Facility, taking into account the properties of the material and its use within the site, is very low.

Hence, the risk of a diesel fire is minimal, provided the storage is designed in accordance with code requirements (in particular AS1940).

Overall Individual Risk of Fatality

For the present development, the risk of fatality of 1 pmpy does not extend beyond the Delta Electricity Facility's boundaries and is therefore well away from the residential areas.

Note that all data used in this risk assessment are for a plant operating 100 % of the time. The quantitative risk results are valid, though highly conservative, for the plant under the expected operating conditions for approximately 5 % of the year for Stage 1 and approximately 90 % of the year for Stage 2.

Overall Societal Risk of Fatality

The above criteria for individual risk do not necessarily reflect the overall risk associated with any proposal. In some cases for instance, where the 1 pmpy contour approaches close to residential areas or sensitive land uses, the potential may exist for multiple fatalities as the result of a single accident. Comparative assessments of such cases involves the calculation of societal risk, however, as the risk of fatality of 1 pmpy does not extend beyond the Facility boundaries the concept of societal risk is not applicable for the proposed development.

Transport Risk

The review of road transport risks concludes that the risk associated with the transport of dangerous goods and potentially hazardous materials to the Site is very low.

15.4.3 Risk Results

The qualitative and quantitative analysis showed that:

Individual Risk of Fatality: The risk of fatality at the nearest residential area is well below the criterion for new installations of one chance in a million per year (1×10^{-6} per year) and remains within the Facility boundary.

It follows that the 10×10^{-6} per year fatality risk contour (relevant for open spaces) remains well within the Facility boundary and does not encroach into any open spaces. The criterion for open spaces is therefore satisfied.

It also follows that the 50×10^{-6} per year fatality risk contour (relevant for industry and business) remains well within the site boundaries and does not encroach into any business or industrial zones. The criterion for industrial and business zoning is therefore satisfied.

Injury Risk: The 50×10^{-6} per year injury risk contour remains well within the Facility boundary. The criterion for injury risk is therefore satisfied.

Propagation Risk: The 50×10^{-6} per year propagation risk contour remains well within the Facility boundary. The criterion for propagation risk is therefore satisfied.

Societal Risk: As the risk of fatality does not extend anywhere outside the Delta Electricity Facility boundary, it is considered that the proposed development does not have a significant impact on societal risk.

Transport of Dangerous Goods: The risk associated with the transport of dangerous goods and potentially hazardous material to the site is very low.

Even though many of the assumptions in this PHA are conservative, the results show that the risk associated with this development is very low. The most stringent risk criteria, as required by the Department of Planning, are adhered to.

15.5 Assessment of Potential Impacts – Cumulative

The analysis showed that none of the incidents identified for the Delta Electricity Facility will reach the EnergyAustralia Facility at radiation levels where propagation may occur. Similarly, none of the incidents identified for the EnergyAustralia facility will reach the Delta Electricity Facility at radiation levels where propagation may occur. Hence, there is no increase in the risk associated with the Delta Electricity Facility from the adjacent EnergyAustralia Facility. Further, the Delta Electricity Facility does not increase the risk associated with the EnergyAustralia Facility.

The analysis showed that, in terms of cumulative risk impact, there is no increase in the risk associated with each Facility (Delta Electricity and EnergyAustralia) from having two Facilities on the Marulan Site.

15.6 Mitigation Measures

A summary of the mitigation measures in terms of hazard is provided **Table 15-5.** The phase of implementation is indicated in the table by *Cons* – Construction *Ops* – Operation, *Design* and *Planning*.

Table 15-5 –Summary of Mitigation Measures

Mitigation Measures	Implementation of mitigation measures	
	Delta Electricity Facility	Cumulative
In accordance with Department of Planning's HIPAP No. 3 *(Environmental Risk Impact Assessment Guidelines),* the safety assessment process would continue throughout the design, construction and commissioning of the Facility to refine and update the outcome of the development approval / environmental risk process.	✓ (Design & Ops.)	
An assessment of the safety management system implemented and used at the Site, specifically as it applies to the proposed hazardous materials handling, pipelining and storages, would be conducted within the first year of operation.	✓ (Ops.)	
Leak detection equipment to be used in areas where high risk natural gas piping is used (high likelihood of leak and/or confined locations).	✓ (Design & Ops.)	
The detailed design of the turbine housing and associated equipments would clearly outline to basis of safety used to ensure that explosive situations do not arise (the risk is rendered negligible). Reference should be made to European ATEX Directive and the UK HSE PM84 or other guidance / regulation of equivalent safety.	✓ (Design)	
Fire protection inside the turbine housing to be determined, including use of explosion panels and use of fire retardant material.	✓ (Design)	
Installation of an automatic valve at site boundary which would isolate natural gas supply to the site in case of a major leak at one of the natural gas pipes on site. The reliability of this automatic valve to close on demand is set as 95% (SIL1). A major leak is regarded as one which results in a mass flow through the hole in the pipe of 5 kg/s or more.	✓ (Design)	