AGRI ENERGY LIMITED

PROPOSED ETHANOL PRODUCTION FACILITIES

PRELIMINARY HAZARD ANALYSIS

OAKLANDS SITE

ENVIRONMENTAL RESOURCES MANAGEMENT AUSTRALIA PTY LTD

PREPARED FOR:	**Jodi Kelehear** **ERM**
DOCUMENT NO:	**J20149-100-002**
REVISION:	**1**
DATE:	**27 February 2007**

Sherpa Consulting Pty Ltd (ABN 40 110 961 898)
Phone: 61 2 9412 4555
Fax: 61 2 9412 4556
Web: www.sherpaconsulting.com

DOCUMENT REVISION RECORD

REV	DATE	DESCRIPTION	PREPARED	CHECKED	APPROVED	METHOD OF ISSUE
DRAFT	2/27/2007	Draft for internal review	P Johnson	I Ninic	-	-
A	8/02/2007	Draft for Review	P Johnson I Ninic	I Ninic G Peach	G Peach	PDF email
0	16/02/2007	Formal issue	P Johnson I Ninic	G Peach	G Peach	PDF email
1	27/02/2007	Re-issued incorporating client comments	I Ninic	G Peach	G Peach	PDF email

RELIANCE NOTICE

This report is issued pursuant to an Agreement between SHERPA CONSULTING PTY LTD ('Sherpa Consulting') and Environmental Resources Management Australia Pty Ltd which agreement sets forth the entire rights, obligations and liabilities of those parties with respect to the content and use of the report.

Reliance by any other party on the contents of the report shall be at its own risk. Sherpa Consulting makes no warranty or representation, expressed or implied, to any other party with respect to the accuracy, completeness, or usefulness of the information contained in this report and assumes no liabilities with respect to any other party's use of or damages resulting from such use of any information, conclusions or recommendations disclosed in this report.

Title:	**QA Verified:**
Agri Energy Limited **Proposed Ethanol Production Facilities** **Preliminary Hazard Analysis** **Oaklands Site**	K BROOKES
	Date: 27 February 2007

CONTENTS

TABLES

FIGURES

1. EXECUTIVE SUMMARY AND RECOMMENDATIONS

1.1. Purpose and Scope

Agri Energy Limited (AEL) is in the process of seeking project approval for the development of an ethanol production facility at Oaklands, New South Wales (NSW), under Part 3A of the *Environmental Planning and Assessment Act, 1979 (*EP&A Act). The production facility will be capable of producing 200 megalitres (ML) of ethanol annually and will store petrol (used to denature the produced ethanol) and Liquefied Natural Gas (which is vaporised and used as fuel gas). In addition, several holding dams containing water, an effluent treatment facility and an irrigation area will be developed. The irrigation area will be irrigated with process wastewater as part of a wastewater recycling scheme. The proposal will have a development cost exceeding $30 million and is therefore a 'major project' to which Part 3A of the EP&A Act applies. As such, it will be determined by the Minister for Planning.

ERM advised Sherpa that the Director General's Requirements (DGRs) for the proposed facility include the following requirement:

Hazards and Risk – including a Preliminary Hazard Analysis (PHA) in accordance with Hazardous Industry Planning Advisory Paper No 6 – Guidelines for Hazard Analysis and Multi Level Risk Assessment and details of fire/ emergency measures and procedures

Environmental Resources Management Australia Pty Ltd (ERM) has engaged Sherpa Consulting Pty Ltd (Sherpa) to undertake the PHA.

This PHA relates to the Oaklands development. Separate applications for approval are being lodged by AEL for 200 ML ethanol production facilities at Condobolin and Coleambally in NSW.

1.2. Study Objectives

The need for a PHA was triggered by the DGRs, and the process will be in accordance with the Department of Infrastructure, Planning and Natural Resources (DIPNR) Hazardous Industry Planning Advisory Paper (HIPAP) No 6 – Guidelines for Hazard Analysis (Ref.1) and DIPNR Multi Level Risk Assessment Ref.2).

Reference is also made to the screening methods outlined in NSW State Environmental Planning Policy No. 33 (SEPP33 - Ref.3).

1.3. PHA Process

The DIPNR Multi-level Risk Assessment Guideline (Ref.2) was consulted to identify the most appropriate level of risk assessment.

This PHA is based on a Level 2 Risk Assessment where the results are sufficiently quantified to allow an assessment of the offsite risk levels against acceptance criteria.

The risk assessment process and risk acceptance criteria set out in HIPAP No. 6 (Ref.1) and HIPAP 4 (Ref.4) were followed.

1.4. Limitations

- This PHA is based on data supplied by AEL, Process Design and Fabrication (PDF) and ERM. Distances to the site boundary and bund dimensions were interpreted from the preliminary site layout plans.
- This report contains assumptions relating to site layout and process conditions. These are identified in the report.
- Detailed design information for the proposed Liquefied Natural Gas (LNG) storage was not available at the time of this PHA (Revision A); therefore, a location was selected based on the outcome of a risk-based site layout review undertaken in accordance with the requirements of *AS 3961-2005 The storage and handling of liquefied natural gas (Clause 2.6.3)*. Assumptions made in this study regarding the LNG storage design are given in APPENDIX 4.
- The DGRs for the site included the preparation of a PHA in accordance with DIPNR Multi-level Risk Assessment Guideline (Ref.2); hence, this document does not include a comprehensive review against *SEPP 33*; however, Section 4 provides a discussion of *SEPP 33* issues relating to Dangerous Goods transport.

1.5. Findings

- The PHA was carried out in accordance with DIPNR guidance: *HIPAP 6* and *Multi-level Risk Assessment*.
- A Hazard Identification (HAZID) review meeting was held between the designers, PDF, and Sherpa to identify potential hazard scenarios, their causes, consequence and safeguards in place in the design.
- The outcome of the HAZID was a set of 7 Major Accidents (MAs) with the potential for offsite impact, which were carried forward for quantification. These were:
  - Ethanol full surface bund fire in the bulk storage area;
  - Petrol full surface bund fire in the bulk storage area;
  - Ethanol spray fire in the distillation process area;
  - Ethanol pool fire at the tank truck loading area;
  - Petrol pool fire at the tank truck loading area;
  - LNG pool fire at the LNG storage vessels/ tanker unloading area; and
  - Unignited LNG pool at storage vessels/ tanker unloading area, leading to evaporation, vapour cloud dispersion and flash fire, if ignited.
- The consequences of the MAs identified were assessed using the proprietary consequence modelling packages *Shell FRED* (Version 4) and BREEZE LFG Fire/ Risk Version 5.0.3 (incorporating DEGADIS). It was found that these events would

not have the potential for offsite impact (fatality, injury or offsite escalation) and thus would not have the potential for impact at adjacent public places.

- Accidental emissions (spills) of ethanol, petrol and other chemicals will be captured in the tank bunds and directed to the site interceptor for recovery. The LNG storage vessels will be the double-containment (vessel-within-vessel) type; therefore, leaks from the primary containment vessel would be captured by the secondary containment vessel. In the event of an LNG leak outside the secondary vessel, the slope of the floor beneath the vessels would direct the spill to the drainage system. Therefore, the potential effects of an accidental emission will not affect the long-tem viability of the ecosystem of any sensitive natural environmental areas.
- Whilst there is potential for escalation between the tanks in the Ethanol and Petrol storage area, the consequences would be no worse than the full surface bund fire modelled (found not to have potential for offsite impact).
- Ethanol and petrol full-surface bund fires would not have the potential to escalate to the LNG vessels (due to large separation distance). Conversely, a fire at the LNG vessels would not have the potential to escalate to the ethanol and petrol bulk storage tanks.
- The development was screened against *SEPP 33* and it was found that a Route Selection Study (Ref.5) may be required due to the high volume of vehicle movements proposed to transport ethanol from the site.

1.6. Conclusions

- The identified hazardous events that have the potential to occur at the site, viz. ethanol and petrol fires, would not have the potential for offsite impact (fatality, injury or offsite escalation); therefore:
    - The offsite individual and societal risk of injury, due to heat radiation, from the development would not exceed the 50 x 10^{-6} per year NSW Land-Use Safety Planning risk criteria for heat radiation injury.
    - The risk of accident propagation offsite from the development would not exceed the 50 x 10^{-6} per year NSW Land-Use Safety Planning risk criteria for accident propagation.
- The findings of the risk assessment, undertaken in accordance with the requirements *AS 3961-2005 The storage and handling of liquefied natural gas (Clause 2.6.3)*, demonstrated that there is sufficient land at the proposed site for the LNG Storage Vessels to be located such that the consequences of a Maximum Design Spillage would not have the potential to escalate to on-site protected places (e.g. ethanol and petrol bulk storage tanks) and would not have the potential to impact public places beyond the site boundary.
- The potential effects of an accidental emission will not affect the long-tem viability of the ecosystem of any sensitive natural environmental areas.

1.7. Recommendations

1. As the design develops the project is required to complete a number of other safety and risk studies in accordance with the NSW Department of Planning Seven Stage Approval Process and as requested by the Director General, viz.:

Project Phase	Safety Study
Design Stage	Hazard and Operability Study
	Final Hazard Analysis (updating this PHA)
	Fire Safety Study
	Emergency Plan
Construction/Commissioning Stage	Construction Safety Study
Operational Stage	Safety Management System
	Independent Hazard Audit

2. It is recommended that a Safety Management System is developed in accordance with HIPAP 9 (Ref.6).

3. It is recommended that the Emergency Plan is developed in accordance with HIPAP 1 (Ref.7).

4. It is recommended that assumptions made in this report be re-checked when more detailed information is available; e.g. the distance from the Ethanol Storage area to the site boundary should be checked to ensure that the separation distance of greater than 85m is maintained such that the consequences of a fire in this area remain on site (see Section 5.2).

5. Subject to the Director General's requirements, a Route Selection Study (Ref.5) may be required due to the volume of vehicle movements proposed to transport the produced ethanol and the quantity of LNG delivered to the site per delivery.

6. This PHA (Revision A) selected a location for the LNG facility based on the outcome of the risk-based review against *AS 3961-2005 Clause 2.6.3*. Should the detailed design require another location to be chosen, a 292 m separation distance should be maintained between the vessel and the site boundary, as discussed in Section 5.3 of this report (if the quantity of stored LNG exceeds 100 m^3). Should the final design require an LNG storage capacity less than 100 m^3, vessel location and spacing can be determined from *AS 3961-2005 Clause 2.6.3 (i.e. rather than Clause 2.6.2).*

7. The design of the floor grade beneath the LNG vessels must ensure that any LNG spills will:
   - drain away from the LNG vessels (and other stores of flammable, combustible or hazardous goods) to a safe location; and
   - not enter any open drains, creeks, waterways or other feature where water may be present at any time.

8. It is recommended that the latest revisions of the appropriate Australian Standards (including those identified in this document, viz.: AS 1940, AS 3961, Building Code of Australia, AS60079.10) are consulted during the Design Stage.

2. SITE AND PROCESS DESCRIPTION

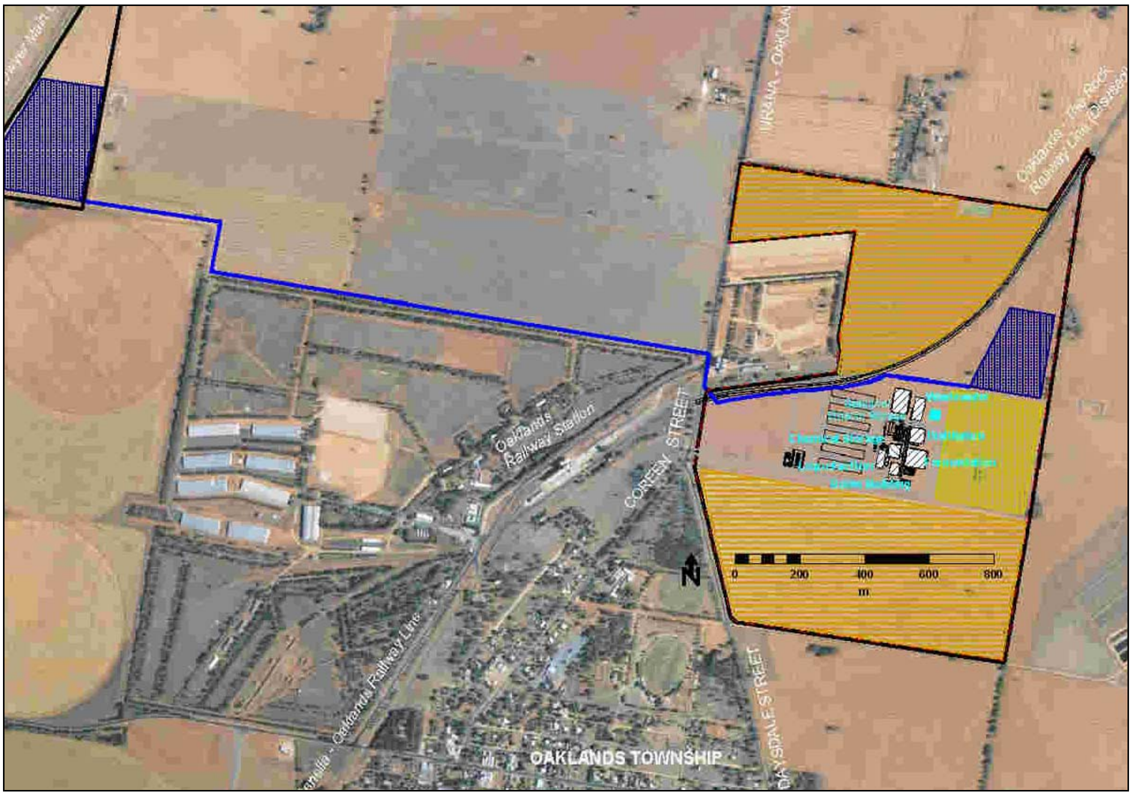
2.1. Location

The site of the proposed ethanol production facility is wholly within the local government area of Urana. It is accessed from Coreen Street at a point approximately 350m north-east of Oaklands. Oaklands is situated in the Murray region of NSW, approximately 615km south-west of Sydney and 105km north-west of Albury.

The site is approximately 130 hectares (ha) and comprises one land parcel, identified as Lot 2 of Deposited Plan (DP) 861032. In addition, there will be an offsite pump station, water storage and subsurface pipeline which will occupy a portion of Lots 64 and 68 of DP 756402, adjacent to O'Dwyer Main Channel. An aerial photograph showing the location of the site is presented in Figure 2.1. Topography is generally flat, as is typical of the surrounding landscape.

The site is bounded by Daysdale Street, Coreen Street, Urana Road and the Ray Brooks & Co. bulk grain storage and terminal to the west and by open agricultural land with scattered rural residences to the north, east and south. These include a rural residence approximately 170m north-west of the site and an unoccupied residence approximately 170m from the northern site boundary. Land on the western side of Daysdale Street, opposite the south-west portion of the site, is occupied by a small area of dense vegetation and a recreational sporting oval, that is at the northern extent of the Oaklands township. The disused Oaklands–The Rock rail line runs through the site. The nearest residential area to the site is the Oaklands township, approximately 350m southwest of the site access. The closest water body is Nowranie Creek, approximately 700m to the north.

FIGURE 2.1: SITE LOCATION

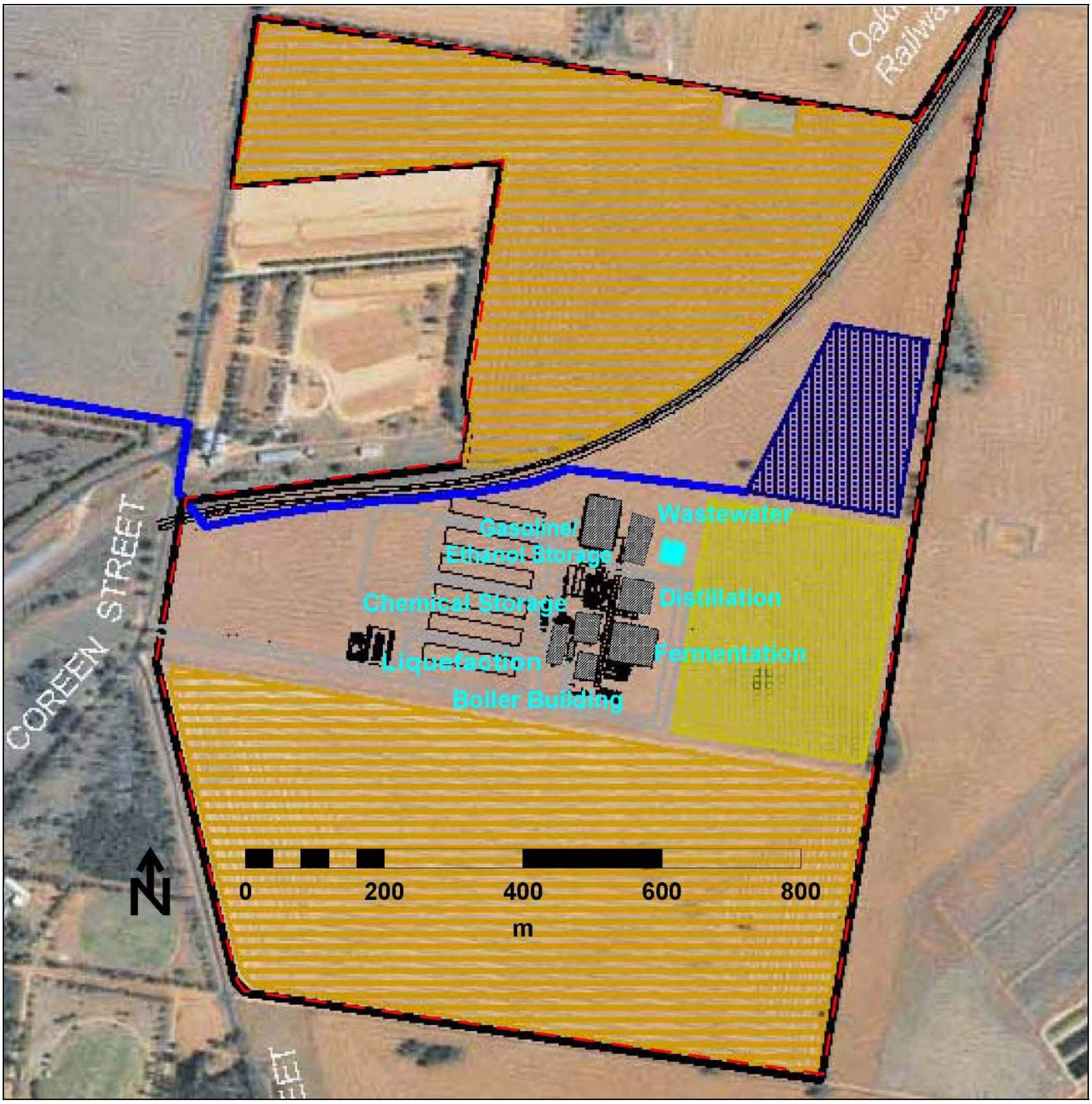


The ethanol production plant will have a footprint of approximately 300m x 300m and will include the following areas:

- Ethanol Production
  - Grain storage
  - Grain milling
  - Fermentation
  - Liquefaction and saccharification
  - Distillation
  - Ethanol storage
- Utilities
  - Steam Raising
  - Petrol Storage
  - Chemical storage
  - Liquefied Natural Gas (LNG) Storage
- Other
  - Maintenance workshop and general storage
  - Office/administration

The main areas are shown in Figure 2.2. Note: the layout and location of the LNG storage vessels is not shown in Figure 2.2 (see Section 2.2).

FIGURE 2.2: PROCESS PLANT LAYOUT



2.2. LNG Storage

AEL has indicated that methane derived from Liquefied Natural Gas (LNG) will be used as a fuel for direct-fired equipment at the ethanol plant.

Detailed design information for the proposed LNG storage was not available at the time of this PHA (Revision A). Therefore, typical design data was agreed with AEL for an LNG storage and vaporization system. Key assumptions were:

- total LNG storage capacity would be 400 m^3 (2 x 200 m^3 vessels);

- LNG vessels would be the pressurised, double-containment (vessel-within-vessel) type (such that leaks from the primary containment vessel would be captured by the secondary containment vessel);
- LNG vaporization would be undertaken using air-driven vaporiser/s (i.e. not a direct-fired type, which may be a potential ignition source); and
- LNG storage facility will be designed to meet the requirements of the Australian LNG industry standard *AS 3961-2005 The storage and handling of liquefied natural gas* (Ref.8).

A summary of the assumptions regarding the design and process conditions of the LNG storage is provided in APPENDIX 4.

For aggregate LNG storage quantities exceeding 100 m^3, Clause 2.6.2 (Risk Assessment) of AS 3961 is applicable and a risk assessment, in accordance with the requirements of AS 3961-2005, is required to ensure that the layout of the LNG storage facility is optimised with respect to safety and that the risks of the LNG storage facility are manageable.

Accordingly, a risk-based review against AS 3961-2005 Clause 2.6.3 was undertaken and the outcomes of this review were considered for locating the LNG storage facility for the purpose of this PHA. Should the detailed design require another location to be chosen, a 292 m separation distance should be maintained between the vessel and the site boundary, as discussed in Section 5.3 of this report.

> ***NOTE:*** *Should the final design require an LNG storage capacity less than 100 m^3, vessel location and spacing can be determined from AS 3961-2005 Clause 2.6.3 (i.e. rather than Clause 2.6.2).*

The land on which the ethanol plant will be constructed is essentially flat and the slope of the ground beneath the LNG vessels will ensure that any LNG spills will drain away from the LNG vessels (and other stores of flammable, combustible or hazardous goods) to a safe location and will not enter any open drains, creeks, waterways or other feature where water may be present at any time.

2.3. Process

2.3.1. Grain Receival and Storage

Grain is hauled to the site by truck and unloaded at one of two unloading areas where the grain will be stored prior to processing:

- a grain receival platform where the grain will be discharged into a collection hopper and conveyed to one of two 7000 tonne storage silos; and
- a grain storage area, which will consist of six separate grain bunkers, each approximately 30m wide, 200m long and up to 20m high, with a capacity of 20,000 tonnes. Once a bunker is formed, it will be covered with plastic tarpaulin to protect the grain from parasites, birds, rain and wind.

A Grain Receiving Dust Collector collects the dust from the grain unloading operation and returns it to the process ahead of the hammermill.

The ethanol production process requires a constant supply of grain. At full production of 200 ML of ethanol per year, the plant will require approximately 1600 tonnes of grain per day or 67 tonnes per hour. This grain will be fed to the plant from a small 'shift silo' with a 1300 tonne capacity. Grain is to be transported to the shift silo via two ways, dependent on whether the grain is being sourced from the grain storage silos or from the bunker storage area.

For retrieval from the storage silos, a screw feeder and elevator at the bottom of the source silo will be used to convey grain to the shift silo. This system will include dust extraction and filtering facilities to eliminate dust emissions.

For retrieval from the bunker storage area, grain will be picked up by a front-end loader and fed into a mobile dump hopper positioned over a belt conveyor. The belt conveyor will feed the grain to the main feed conveyor and on to a screening station which will include a dust collecting and filtering system to eliminate dust emissions. The grain will then be elevated to the shift silo.

2.3.2. Milling and Slurry Preparation

As part of the production process the grain needs to be milled and then mixed into slurry via the following process:

1) grain from the shift silo will be gravity fed to the hammermill where it is milled;

2) the hammermill dust collectors extract dust by vacuum from appropriate points in the milling system circuit and direct it to a bag filter, which will collect the dust and return it to the mill discharge conveyor;

3) a monitored weight of milled grain flour will be mechanically conveyed to a pug mixer, where a 'slops mix', comprising recycled process water from the distillation and evaporation operations will be added to form a slurry of appropriate density;

4) from the pug mixer, the slurry mix will be directed to a mixing tank where additional slops or process water can be added to make up the correct slurry density and percent solids; and

5) the mixed slurry preparation (mash) will be pumped from the mixing tank to the pre-liquefaction tank via one of two discharge pumps (operating and spare) for liquefaction.

2.3.3. Chemical Preparation

A separate building has been designed to receive and prepare a range of chemicals used as part of the ethanol production process. The chemical preparation area consists of a series of small mixing tanks fitted with access platforms, mixing agitators (where required), dosing delivery pumps and pipe work. Packaged chemicals will be fed by forklift or manually from the bag or container into the respective mixing tank. Once prepared, the chemical mix is to be piped to the required process stage.

2.3.4. Liquefaction Stage

Liquefaction is the process of converting insoluble starch in the mash to a soluble starch mix by enzyme reaction at an elevated temperature. An enzyme mix prepared in the chemical preparation area is metered as a liquid into the pug mixer and the pre-liquefaction tank.

The mash is strained and heated, and then pumped to the liquefaction tank in the preparation building for processing of the insoluble starch. The liquefaction tank is sealed, insulated and agitated and the reaction takes up to four hours depending upon grain type.

From the liquefaction tank the mash is pumped to the pre-saccharification tank via mash coolers, which flash cool the mash with non-contact cooling water and lower its temperature to approximately 60 degrees Celsius.

2.3.5. Saccharification Stage

Saccharification is the enzymatic conversion of the soluble starch to glucose. The reaction occurs in the pre-saccharification tank which is also sealed, insulated and agitated, and continues in the pre-fermentor and the fermentor tanks. The reaction requires the addition of another enzyme mix, which is metered as a liquid into the pre-saccharification tank.

From the pre-saccharification tank the mash is pumped to a pre–fermentor tank via coolers which again flash cool with non-contact cooling water. Vented emissions are collected and sent to the process vent scrubber, where they are scrubbed, using chilled water. Emissions from the scrubber are discharged to the atmosphere, and the water is returned to the beer well for distillation of the dissolved alcohol.

2.3.6. Fermentation Stage

Fermentation is the conversion of glucose to ethanol and carbon dioxide by the action of yeast. Propagated yeast and other chemicals that promote and sustain the reaction are added to the pre–fermentor tank. The mash containing yeast and nutrient is then pumped to one of three stainless steel fermentor tanks. Once a tank is filled, it is allowed to react for the required time to achieve maximum conversion of sugars to ethanol (around 45 to 55 hours). This process produces a fermented mash called beer which is emptied to a beer well. The empty tank is then cleaned by the addition of cold caustic soda solution. Once cleaned the tank is filled again for the next cycle. Fermentation is a batch process that occurs continuously by using all three fermentor tanks in series.

The carbon dioxide produced by the fermentation reaction is vented to a fermentation vent scrubber where water is used to scrub residual amounts of ethanol from the carbon dioxide. The cleaned, scrubbed carbon dioxide gas is emitted to atmosphere while the scrubber water is pumped into the beer well.

The beer contains about ten per cent ethanol in addition to non-fermentable grain solids. The beer well acts as a buffer tank to receive the reacted ethanol and mash mix for feed to the distillation stage.

2.3.7. Distillation, Evaporation and Dehydration Stage

For distillation, beer is pumped from the beer well in the fermentation area to the stainless steel mash distillation column, which will contain a number of heating trays. The column operates under a vacuum at a temperature of up to 125 degrees Celsius and is approximately 12 metres high. Distillation occurs in this column and involves boiling off the ethanol from the beer with steam to produce a hydrous ethanol product containing 95 per cent ethanol and five per cent water. The steam is produced from three boilers which are fuelled by vaporised LNG.

The hydrous ethanol is then dehydrated to a fuel ethanol grade by superheating vapour and liquid from the top of the rectifier distillation column and transferring it to molecular sieve vessels, which remove any water from the ethanol product. Product ethanol is then cooled, filtered and transferred to the ethanol storage area.

Vapours from the distillation area condenser systems flow to the process vent scrubber where chilled water is used to scrub residual amounts of ethanol from the air before it is discharged from the scrubber stack to the atmosphere. The water from the scrubber is pumped to the beer well.

The by-product of distillation is slurry containing all unfermentable products, principally water and distiller’s grain. This slurry is transferred from the base of the mash distillation column to a centrifuge, which removes the majority of water. The wet distiller's grain can then be extracted from the centrifuge as a wet cake.

The liquid by-product is transferred to a slops tank where approximately 60 per cent is returned to liquefaction for addition to the milled grain flour at the start of the process. The remaining 40 per cent is evaporated in a continuous evaporator to reduce the water content and thicken the product to a more concentrated form (syrup), which is pumped to a syrup collection tank. The water stream from the evaporator system is used as process water at the mixer or flows to the secondary treatment plant, which discharges to the effluent dam for pumping to the 55 ha irrigation area.

The wet cake (extracted from the centrifuge) is then combined with the syrup in a paddle mixer to form a product containing approximately 30% solids, called Wet Distillers Grain and Solubles (WDGS). Half of this product will be sold in this form. The remaining half will be transferred to a flash dryer where it is dried by steam to produce Dried Distillers Grain with Solubles (DDGS) which has approximately ten per cent moisture content. The dryer exhaust passes through a Thermal Oxidizer which incinerates the emissions from the dryer and then discharges to the atmosphere. The DDGS is cooled and conveyed to the storage and load-out area.

2.3.8. Distillers Grain Storage and Dispatch

WDGS and DDGS will be stored in a dual-purpose shed, which has a concrete bunded bunker for WDGS storage and open-fronted concrete bins for DDGS storage. WDGS will be pumped into B-doubles or semi trailers for trucking to market. A front end loader will be used to pick up DDGS from the bins and load B-doubles or semi trailers for trucking to market. Dust generated during the DDGS loading process is to be collected by the DDGS Load-out Dust Collector.

2.3.9. Ethanol Storage and Dispatch

The cooled ethanol will be transferred to one of two Anhydrous Ethanol Storage Tanks (approximately 1800 m^3 each). Occasionally, problems with the plant may result in production of off-spec product. If this occurs, the product will be diverted to an Off-Spec Storage Tank.

All storage tanks are vented through a vent pipe fitted with an in-line flame arrester and a breather vent valve. All vapours from the Petrol unloading and ethanol loading are collected in vapour recovery lines and sent to the road tanker or the source tank, respectively.

For the production of fuel grade ethanol, Petrol (denaturant) from the Petrol Storage Tank (approximately 170 m^3) is to be metered continuously into the pure ethanol stream during transfer from the product storage tank to the road tanker. This will yield a finished product containing five per cent denaturant. The denaturant tank is sized to hold sufficient denaturant to cover ten days ethanol production.

Ethanol product will be transported to market via B-double trucks. These trucks will be filled at a dedicated loading area designed to comply with the requirements of AS1940:2004.

2.4. Hazardous Materials

Hazardous substances handled at the site include:

- Natural Gas (via LNG), used for steam raising;
- Ethanol (product);
- Petrol (denaturant);
- Chemical additives
    - Sulphuric Acid;
    - Sodium Hydroxide;
    - Nitric Acid;
    - Aqueous Ammonia; and
    - Urea.

In addition, grain is included due to its potential for dust explosions, and high pressure steam is considered due to the potential for steam boiler explosions. The approximate quantities of each substance to be stored on site are given in Table 2.1.

TABLE 2.1: QUANTITIES OF HAZARDOUS SUBSTANCES STORED AT SITE

Material	UN No	DG Class	PG	Quantity	Unit
Liquefied Natural Gas	1972	2.1	-	400[(b)]	m^3
Ethanol	1170	3	II	3600	m^3
Petrol	1203	3	II	189	m^3
Sulphuric Acid (94%)	1830	8	II	9,000[(c)]	kg
Sodium Hydroxide (20%)[(a)]	1824	8	II[(a)]	23,000[(c)]	kg
Nitric Acid (20%)[(a)]	2031	8	II[(a)]	9,000[(c)]	kg
Aqueous Ammonia (25%)	2672	8	III	23,000[(c)]	kg
Urea	Not classified			23,000 [(c)]	kg
Grain	Not classified			Silo: 2x7,000,000 Shift Silo: 1x1,300,000	kg
Steam	Not classified			N/A	
(a) Assumed concentration. (b) Assumed; see APPENDIX 4. (c) Assumed based on tank truck capacity.					

The location of each substance (except LNG – see Section 2.2) is shown in Table 2.2, using areas identified in Figure 2.2.

An AS 3961-compliant location for the LNG vessels was determined in this study, as illustrated in Figure 5.1 and Figure 5.2.

TABLE 2.2: LOCATION OF HAZARDOUS SUBSTANCES

Area	Stored Substances
Petrol / Ethanol Storage	Ethanol, Petrol
Chemical Storage	Sulphuric Acid Sodium Hydroxide Nitric Acid Aqueous Ammonia Urea
Grain Storage & Milling	Grain
Boiler House	Steam
LNG Storage Compound (An AS 3961-compliant location for the LNG vessels was determined in this study – see Figure 5.1 and Figure 5.2)	Liquefied Natural Gas

3. HAZARD IDENTIFICATION

3.1. Overview

The hazard identification exercise comprised:

- review of hazards implicit in the chemicals and materials handled at site;
- review of significant incidents in the ethanol processing industry; and
- hazard identification brainstorming session between PDF (project design engineers) and Sherpa, based on available information from a similar plant at Swan Hill in Victoria.

Hazard identification for the LNG storage facility was based on guidance in *AS 3961-2005 The storage and handling of liquefied natural gas* and the experience of the consultant in undertaking safety-related studies for the LNG industry.

The identified hazards were then extended and developed into hazardous scenarios which could be carried forward for further analysis.

NOTE: *The HAZID findings for the ethanol manufacturing process (Appendix 1) were used as the basis for the PHA studies undertaken for all three proposed sites, viz.: Condobolin, Oaklands and Coleambally.*

3.2. Hazardous Substance Review

For each substance, chemical and hazardous properties were obtained from the CHRIS information system published by the US Coastguard (Ref. 9). Full details are presented in APPENDIX 2.

3.2.1. Special Hazards Associated with Liquefied Natural Gas

There are two special hazards associated with LNG:

- Rapid Phase Transition
- Cryogenic Storage Conditions

An unusual property of LNG is its ability to rapidly vaporise on contact with water resulting in a large pressure increase (due to 600 times expansion from liquid to gas). This is known as Rapid Phase Transition (RPT). The likelihood of RPT is greater if water is spilled onto LNG. In the case of LNG spilled onto water, the water would freeze and provide insulation between the LNG pool and the water, thereby reducing the rate at which heat is extracted from the water and, consequently, the likelihood of RPT. However, if splashing occurs as LNG enters the water, RPT is highly likely.

An LNG spill will be very cold (between -160ºC and -140ºC, depending on storage pressure. The resulting spill has the potential to lead to both fatalities and failure of process equipment, supports and pipework due to brittle failure.

It is therefore good engineering practice to provide a slope beneath vessels to ensure that LNG spills are directed away equipment and also from creeks, waterways, drains and other areas where water may be present.

3.3. Review of Significant Incidents in the Ethanol Production Industry

An example of a significant incident involving Ethanol was a large explosion and fire in a 7,000m^3 Ethanol storage tank at Port Kembla in 2002 (Ref 10). This incident showed the importance of not allowing ignition sources near a vessel storing volatile material. The incident, although spectacular resulted in no fatalities and only one injury. Furthermore, the burn marks visible in the photographs of the site show that the thermal radiation effects were relatively limited; unburnt grass is visible less than a tank diameter from the fire.

3.4. Hazard Identification Brainstorming

The HAZID was conducted by using the Process Flow Diagrams and Process Plant Layouts supplied by PDF for an approved 100ML capacity ethanol plant being constructed by AEL at Swan Hill, Victoria, which is at a more-mature design stage than the Oaklands plant and is essentially of the same design, albeit of a smaller capacity.

The following drawings were used:

06SO12-1-FLS101 Rev 0 Flow Diagram for Milling Section

06SO12-1-FLS102 Rev 1 Flow Diagram for Liquefaction Section

06SO12-1-FLS103 Rev 1 Flow Diagram for Fermentation Section

06SO12-1-FLS104 Rev 1 Flow Diagram for Distillation Section

06SO12-1-FLS501 Rev 1 Flow Diagram for Thin Slop Evaporation Section

06SO12-1-FLS107 Rev 0 Flow Diagram for Storage Section

M06062-0301 Rev F Swan Hill Site Plan

Hazards associated with each section of the plant were discussed at the HAZID, and noted within a table. This is presented in APPENDIX 1.

Detailed design information for the proposed LNG storage was not available at the time of this PHA (Revision A); therefore, hazard identification was based on similar facilities in the LNG industry and guidance in *AS 3961-2005*.

3.5. Hazardous Incidents Development

Hazardous incident scenarios were developed for each of the hazardous materials and activities at the site. A hazard identification word diagram is included in APPENDIX 1 and shows all of the scenarios identified. As noted in the Appendix, some potential incidents were considered to have local rather than offsite consequences. These were not carried forward for quantitative analysis of offsite risk levels.

The scenarios not carried forward included:

- Dust/grain fire or explosion in the grain handling area, due to the large separation distance (>100m) to the site boundary. Also there are many safeguards in place to prevent dust accumulation (extraction system), to prevent ignition (earthing) and to detect fire (smoke detectors in the grain elevators).
- Steam loss of containment, as this type of event is limited in effects to the immediate vicinity of the release. Steam lines do not run in close proximity to the site boundary.
- Chemicals loss of containment, as all chemicals stored in bulk have local corrosive effects and are not toxic at distance.
- Methane vapour cloud explosion (deflagration). Whilst a flash fire is considered, the potential for vapour cloud deflagration (explosion) is low due to the low reactivity of methane (compared with, e.g. ethylene) and the low-level of equipment congestion in the vicinity of the LNG storage area.

3.6. Scenarios for Further Assessment

Hazardous incident scenarios identified in APPENDIX 1 with the potential for offsite impacts were considered to be 'significant' hazardous incidents (major accidents).

The major accidents identified in relation to Ethanol, Petrol[1] and LNG were consolidated into a set of discrete incidents to allow a quantitative model to be developed. These are summarised in Table 3.1, Table 3.2 and Table 3.3, respectively.

Consequence analyses undertaken for these scenarios are summarised in Section 5.

TABLE 3.1: MAJOR ACCIDENTS – ETHANOL

ID	Plant Area / Activity	Plant Items	Risk Event	Causes	Consequence to be Modelled
E1	Tanker loading / unloading	Loading / unloading hoses	Release of product from loading point, and running pool fire if ignited	Hose failure (faulty) / crimped connection failure Could be caused by wear and tear, defect, etc Operator error making connection	Pool fire contained within paved area by kerbing
E2	Storage	Ethanol Storage Tanks	Total catastrophic tank failure and full-surface bund leak.	Tank mechanical failure. External impact.	Fire contained within bunded area.
			Full-surface bund fire, if ignited.	Tank overfill due to control system failure, human error whilst loading.	
			Full-surface bund fire, if leak not detected early and ignition occurs.	Equipment failure (corrosion, drain failure, flange leak, etc.) and release to bund.	
E3	Distillation	Pipework	Ethanol release leading to liquid spray fire on ignition.	Pump seal leak, flange leak etc.	Liquid ethanol spray fire

[1] Note that the terms 'Petrol' and 'Gasoline' are the same substance, and are used interchangeably in this report.

TABLE 3.2: MAJOR ACCIDENTS - PETROL

ID	Plant Area / Activity	Plant Items	Risk Event	Causes	Consequence to be Modelled
P1	Tanker loading / unloading	Loading / unloading hoses	Release of product from road gantry from either site or truck	Hose failure (faulty) / crimped connection failure Could be caused by wear and tear, defect, etc Operator error making connection	Pool fire contained within paved area
P2	Storage	Petrol Storage Tanks	Total catastrophic tank failure and full-surface bund leak.	Tank mechanical failure. External impact.	Fire contained within bunded area.

The Hazard Identification (APPENDIX 1) for LNG Storage identified a number of loss of containment scenarios, involving both liquid and vapour release due to various causes. This PHA addresses two objectives with respect to LNG Storage:

- Confirm that the LNG Storage compound can be sited in accordance with AS 3961
- Assess the risk of the LNG Storage, with respect to the NSW Land-Use Safety Planning Risk Criteria

In order to satisfy the first objective, AS 3961 requires a Maximum Design Spillage to be modelled. This study therefore carried forward the worst-case liquid release scenarios described in Table 3.3.

By complying with the AS 3961 requirements for a worst-case scenario (i.e. confirming no off-site impact and no on-site incident escalation), the LNG Storage compound implicitly complies with the NSW Land-Use Safety Planning Risk Criteria. Therefore, no further scenarios were quantified.

TABLE 3.3: MAJOR ACCIDENTS – LNG

ID	Plant Area / Activity	Plant Items	Risk Event	Causes	Consequence to be Modelled
L1	LNG Tanker unloading	LNG tanker unloading hoses	Release of product from road tanker (conservatively assuming that Excess Flow Valve has failed)	Operator error making connection. (Leak due to hose failure is unlikely, given hose-in-hose design.)	Unconfined pool at 10 minutes after release. Gas dispersion to model potential flash fire[1]. Pool fire modelled based on unconfined pool size.
L2	LNG Storage	LNG Storage Vessels	Release of LNG liquid from storage vessel (conservatively assuming that Excess Flow Valve has failed)	Rupture of liquid pipe below liquid level, downstream of outer vessel. (Leak due to vessel mechanical failure is unlikely, given vessel-in-vessel design.)	Unconfined pool at 10 minutes after release. Gas dispersion to model potential flash fire[1]. Pool fire modelled based on unconfined pool size.

Note 1: The potential for a vapour cloud deflagration (explosion) is low due to the low reactivity of methane and the low-level of equipment congestion in the area where LNG is stored.

4. LEVEL OF ASSESSMENT

4.1. SEPP 33 Screening

The DGRs for the proposed ethanol facility included the following requirement:

Hazards and Risk – including a Preliminary Hazard Analysis (PHA) in accordance with Hazardous Industry Planning Advisory Paper No 6 – Guidelines for Hazard Analysis and Multi Level Risk Assessment and details of fire/ emergency measures and procedures

Therefore, screening against the requirements of *Applying SEPP3*3 (Ref.3) was not required for determination of its applicability to the Ethanol Plant (and hence the requirement for a PHA). However, a *SEPP 33* screening was undertaken to determine the requirement for a dangerous goods transport route selection study.

4.1.1. Vehicle Movements

Table 4.1 provides an assessment of the estimated (and assumed) vehicle movements associated with the plant against thresholds from Table 2 in *Applying SEPP 33*. A route selection study is only required if the quantity of DG transported is above the 'Minimum Quantity Threshold' and the number of movements exceed the 'Movements Threshold'. The Route Selection study (Ref.5) seeks to select a transport route that poses the least risk (due to incidents involving the transported material) to the population adjacent to the road.

TABLE 4.1: GROUPING GOODS BY CLASS AND LOCATION

Material (DG Class)	Vehicles/ week[(a)]	Quantity per load (tonnes) [(a)]	Threshold		Route Selection Study Required?
			Movements	Minimum Quantity	
Ethanol	90	50			
Petrol	4	50			
Total (3)	*94*	*50*	*> 45/ week*	*3 tonnes*	*Yes*
Chemicals (8)	*6 (max)*	*25 (max)[(b)]*	*>30/ week*	*2 tonnes*	*No*
LNG	*≥ 20[(c)]*	*30[(c)]*	*> 30/ week*	*2 tonnes*	*No*

(a) From 0056132_Traffic Table_rev.C, ERM, 2007
(b) Derived from typical road tanker load.
(c) Assumed – see APPENDIX 4.

Therefore, a Route Selection Study (Ref.5) may be required for DG Class 3 material due to the volume of vehicle movements proposed to transport the produced ethanol off the site.

4.2. Level of Assessment

Multi Level Risk Assessment sets out three levels of risk assessment that may be appropriate for a PHA. This document was consulted to identify the level of assessment required in this study.

Level	Type of Analysis	Appropriate if:
1	Qualitative	No major offsite consequences and societal risk is negligible
2	Partially Quantitative	Offsite consequences but with a low frequency of occurrence
3	Quantitative	Where level 1 and 2 are exceeded

Based on the findings of the HAZID it would not be credible to state that no events had offsite impact without more detailed consequence analysis. Hence a Level 1 Assessment was not considered suitable.

It was decided to follow a Level 2 Assessment and calculate the consequences of the Major Accidents in more detail and use the impairment criteria set in *HIPAP 6* (Ref.1) as a basis for assessing the potential for offsite impact.

4.3. Consequence Criteria

The consequences of incidents were noted in Table 3.1, Table 3.2 and Table 3.3, ie

- confined pool fire (ethanol/petrol);
- spray fire (ethanol);
- gas dispersion and flash fire on ignition (LNG); and
- unconfined pool fire (LNG).

4.3.1. Pool & Spray Fires

The applicable thermal radiation criteria for petrol and ethanol fires used in the PHA (consequence analysis) are presented in Table 4.2, and the criteria for LNG are presented in Table 4.3.

TABLE 4.2: THERMAL RADIATION CRITERIA (PETROL & ETHANOL – REF 4)

Heat Radiation Level (kW/m^2)	Effect	Critical Criteria
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds exposure.	Injury
12.6	Significant chance of a fatality for extended exposure.	Fatality
23	Likely fatality for extended exposure; chance of fatality for instantaneous exposure Unprotected steel will reach thermal stress temperatures which can cause failures	Escalation potential

TABLE 4.3: THERMAL RADIATION CRITERIA (LNG – REF 8)

Heat Radiation Level (kW/m^2)	Criterion	Critical Criteria
Pool Fire		
5	Must not reach "*Outdoor off-site areas for public use or assembly where the average daily congregation is 20 people*".	LNG vessel location siting: prevention of potential off-site Injury
10	Must not reach "*Unshielded storage of dangerous goods, LNG vessels, pressure vessels, non- fire-resistant structures*".	LNG vessel location siting: prevention of potential of potential on-site escalation
20	Must not reach "*Streets, highways, and other roads".*	LNG vessel location siting: prevention of potential off-site escalation/ fatality

4.3.2. Methane Flash Fires

Methane evaporating from an unignited LNG maximum design spillage was modelled as leading to a flash fire. The potential for explosion overpressure is low due to the low reactivity of methane (compared with ethylene for example), and the low-level of equipment congestion in the vicinity of the LNG storage area (optimised for safety per AS 3961 Clause 2.6.2).

The flash fire dimensions were conservatively defined as the extent of the vapour cloud for a methane concentration equivalent to half the Lower Flammable Limit (1/2-LFL) for methane (viz. 2.5 vol. %).

Flash fires, unlike pool fires, are short duration events and do not radiate any significant levels of heat for extended durations. The heat radiation criteria adopted for pool fires are therefore not appropriate for flash fires.

Fatality/ serious injury could occur to those physically caught within the flash cloud (but is unlikely for personnel within buildings and other similar protective environments).

A flash fire is unlikely to lead to escalation, due to low thermal radiation, a short event duration and negligible overpressure produced.

Based on this reasoning, this study adopted the following conservative LNG storage vessel site layout acceptability criterion:

- Flash fire resulting from the LNG Maximum Design Spillage must not reach outdoor off-site areas for public use or assembly.

5. CONSEQUENCE ANALYSIS

5.1. Introduction

The consequence analyses were undertaken for the events identified in Table 3.1, Table 3.2 and Table 3.3.

The findings of the consequence analysis undertaken for the LNG Storage vessels were used to optimise the location of the LNG Storage Vessels on the site, in accordance with the requirements of *AS 3961-2005 The storage and handling of liquefied natural gas* (Ref.8).

The findings for the petrol and ethanol fire scenarios are presented in Section 5.2 and the LNG loss of containment scenarios (based on AS 3961 Maximum Design Spillage) are presented in Section 5.3.

5.2. Petrol & Ethanol Fires

The petrol and ethanol fire consequence modelling was carried out using the proprietary consequence modelling package Shell FRED V4[2], was used to evaluate the release rate. The modelling input parameters for petrol and ethanol releases are summarised in Table 5.1.

The consequence analysis findings are reported in Table 5.2 for critical heat radiation levels (Ref.4).

TABLE 5.1: INPUT PARAMETERS (PETROL & ETHANOL)

ID	Location	Substance	Pool Dimensions/ Leak Size	Model	Wind Speed
P1	Road Tanker Loading Area	Petrol	20m x 5m	Trench Fire	$5ms^{-1}$
P2	Petrol Tank Bund	Petrol	10m x 10m	Pool Fire	$5ms^{-1}$
E1	Road Tanker Loading Area	Ethanol	20m x 5m	Trench Fire	$5ms^{-1}$
E2	Ethanol Tank Bund	Ethanol	25m x 25m	Pool Fire	$5ms^{-1}$
E3	Ethanol Release	Ethanol	25mm hole Process conditions[1]: 80ºC, 3 bara	Spray Fire	$5ms^{-1}$

Note 1: Process conditions were assumed, based on information provided.

TABLE 5.2: CONSEQUENCE RESULTS (PETROL & ETHANOL)

ID	Downwind Distance to Critical Thermal Radiation from Fire Centre			Distance (m) to Closest Plant Boundary from Fire Centre	Offsite Impact?
	$4.7\ kWm^{-2}$	$12.6\ kWm^{-2}$	$23\ kWm^{-2}$		
P1	45	35	30	> 200	No
P2	34	26	20	> 180	No
E1	53	32	34	> 200	No

[2] http://www.shell.com/globalsolutions/shellfred/

ID	Downwind Distance to Critical Thermal Radiation from Fire Centre			Distance (m) to Closest Plant Boundary from Fire Centre	Offsite Impact?
	4.7 kWm^{-2}	12.6 kWm^{-2}	23 kWm^{-2}		
E2	84	54	35	> 180	No
E3	38[(a)]	29[(a)]	25[(a)]	> 180	No
(a) Distance from fire source.					

It can be seen from the results that the 4.7 kW/m^2 (injury) contour remains on site for all cases.

It is assumed that the two Ethanol and two Petrol storage tanks are in separate bunded areas that will comply with the requirements of AS1940:2004. However, in the event of a fire, radiation levels greater than 23 kWm^{-2} can affect distances of 20m for Petrol and 35m for Ethanol. These distances are well above the assumed separation distances between the storage tanks, and thus there is potential for escalation. The consequences of the escalation scenario are described by the full surface bund fire scenario, and therefore even if escalation occurred, radiation levels greater than or equal to 4.7 kW/m^2 would not go offsite.

Ethanol and petrol full-surface bund fires would not have the potential to escalate to the LNG vessels (due to large separation distance > 300m).

5.3. LNG Consequence Analysis

5.3.1. General Approach (AS 3961-2005)

Detailed design information for the proposed LNG storage was not available at the time of this study. However, data approved by AEL indicates that the site LNG storage capacity would exceed 100 m^3, such that Clause 2.6.2 (Risk Assessment) of AS 3961 is applicable. Should the aggregate LNG storage quantity be less than 100 m^3 in the final design, vessel location and spacing can be determined from Clause 2.6.3 of AS 3961 rather than Clause 2.6.2.

AS 3961 Clause 2.6.2 states:

A formal risk assessment shall comprise an analysis of the specific features of the site and the installed equipment. The analysis shall take into account amongst other things, the following:

(a) A maximum design spillage, based on a 10 minute escape period for any equipment rupture.

(b) The dispersion of vapour from the maximum design spillage.

(c) Heat radiation levels resulting from the ignition of an escape

The size of the Maximum Design Spillage (over a 10 minute escape period) was evaluated by modelling the release rate from the equipment rupture scenario, based on the proposed LNG storage conditions (shown in Table 5.3). Shell FRED was used to evaluate the release rate.

The consequences of the Maximum Design Spillage were modelled using the proprietary hazard consequence modelling package BREEZE LFG Fire/ Risk Version 5.0.3[3]. Developed and released by Trinity Consultants, the software incorporates DEGADIS, the dense-gas dispersion model developed by the U.S. Coast Guard/ U.S. EPA.

The consequences of a loss of containment of LNG are described in Table 3.3 under scenarios L1 and L2.

5.3.2. LNG Release Calculation

The following scenarios were considered to have the potential for a large LNG loss of containment:

- Scenario L1: LNG road tanker vessel pipe rupture and uncontrolled release of LNG; and/ or
- Scenario L2: LNG storage vessel pipe rupture and uncontrolled release of LNG.

The LNG storage vessels were assumed to be double-containment pressure vessels, provided with lengths of pipework between the inner and outer vessels. Therefore, modelling of a spillage from the pipework exiting the outer vessel included frictional losses in the pipe.

The release rate calculation conservatively assumed that excess flow (or other internal leak-limiting) valves would not activate to minimise/ isolate flow and would not provide a restriction to the flow. A summary of the modelling input data and findings is given in Table 5.3.

TABLE 5.3: SIZE OF LNG MAXIMUM DESIGN SPILLAGE

Parameter	Value		Comments
	Road Tanker (L1)	Storage Vessel (L2)	
Input Data (Assumed)			
Vessel pressure (barg)	3	3	Saturated conditions
Vessel temperature (ºC)	-146.5	-146.5	Saturated conditions
Pipe Diameter (m)	0.08	0.08	Liquid line
Length of pipework upstream of rupture (i.e. between vessel) (m)	7	10	-
Pipe Surface Roughness	1.5E-6	1.5E-6	To account for friction losses inside the pipe

[3] http://www.breeze-software.com/prod/brzSoftware.asp?P=HAZLFG

Parameter	Value		Comments
	Road Tanker (L1)	Storage Vessel (L2)	
Sum of friction loss coefficients (K)	3	3	To account for frictional losses due bends in the pipework.
Rupture (hole) size (m)	0.08	0.08	Full-bore rupture
Findings			
Release rate (kg/s)	21.7	21.0	Shell FRED output
Mass of LNG released in 10 minutes (kg)	13,000	12,600	-

Therefore, the 13,000 kg release (i.e. 21.7 kg/s over a 10 minute escape period) was carried forward as the LNG Maximum Design Spillage, as representative for scenarios L1 and L2.

In order to investigate the potential for adverse consequences from the Maximum Design Spillage to reach potentially sensitive targets, the location of the LNG pool was conservatively selected to be at the centre of the LNG vessels (noting that the floor grade beneath the vessels will ensure that a leak drains away from the vessels and other flammable/ combustible goods stores).

5.3.3. LNG Pool Fire Calculation

The equilibrium pool fire diameter was evaluated to be approximately 10 m based on the information in Table 5.3.

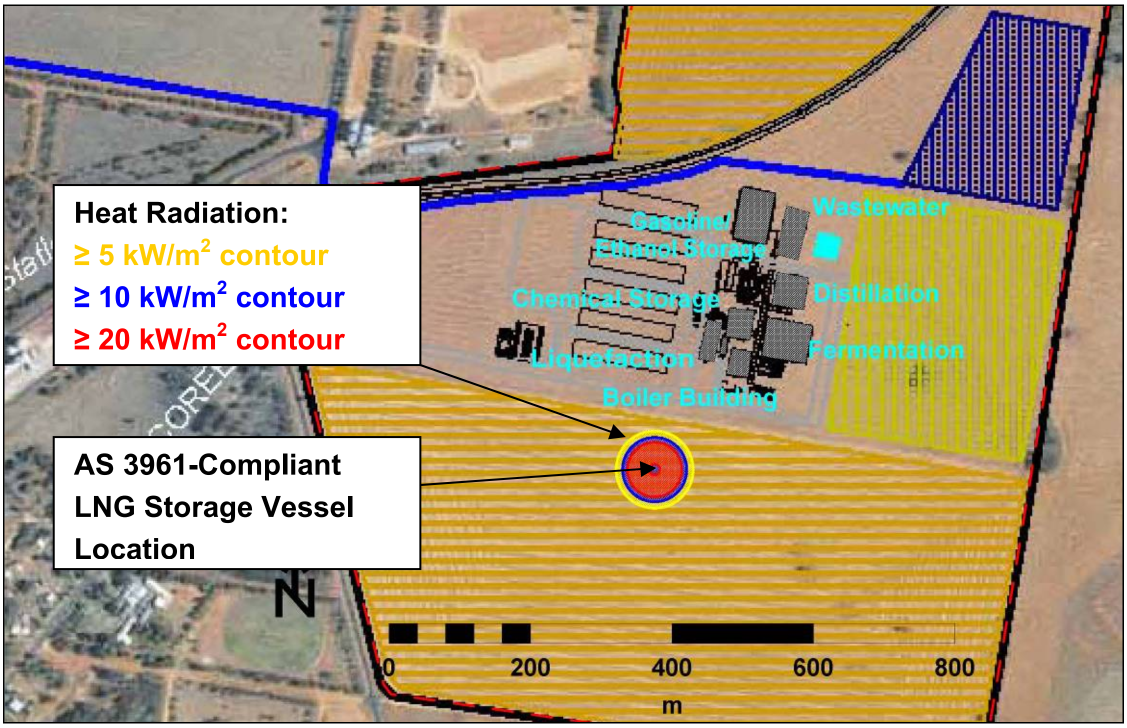
The findings summarised in Table 5.4 indicate that the centre of the LNG vessels should be located more than 52 m from the site boundary and 43 m from the gasoline and ethanol bulk storage areas.

TABLE 5.4: LNG POOL FIRE CONSEQUENCE FINDINGS

Scenario	Radiation (kW/m^2)	Distance to Radiation Level (m) from Pool Centre	Potential Target of Concern
L1/L2	5	52	Site boundary
L1/L2	10	43	Gasoline/ ethanol tanks
L1/L2	20	36	Site boundary

The heat radiation contours, superimposed on an acceptable option (satisfying the AS 3961 criteria) for the location of the LNG storage vessels, are illustrated in Figure 5.1.

FIGURE 5.1: LNG POOL FIRE CONTOUR (LAYOUT PER AS3961-2005 CLAUSE 2.6.2)



A pool fire at the LNG vessel location, illustrated in Figure 5.1, would not have the potential to have an off-site impact or to escalate to the ethanol and petrol bulk storage tanks (due to large separation distance).

5.3.4. Methane Flash Fire

The vapour dispersion calculation was undertaken for two representative wind speed and Pasquill weather stability classes, viz.:

D5 – Neutral, common conditions (D Class) with moderate wind speed (5 m/s); and

F2 – Very stable, rare conditions (F Class – accounts for atmospheric inversion layer) with low wind speed (2 m/s).

The equilibrium unignited-pool diameter was evaluated to be 46 m under D5 conditions and 48 m under F2 conditions. The maximum evaporation rate from the equilibrium pool, at 600 seconds, was evaluated to be 21.5 kg/s under D5 conditions and 21.2 kg/s under F2 conditions.

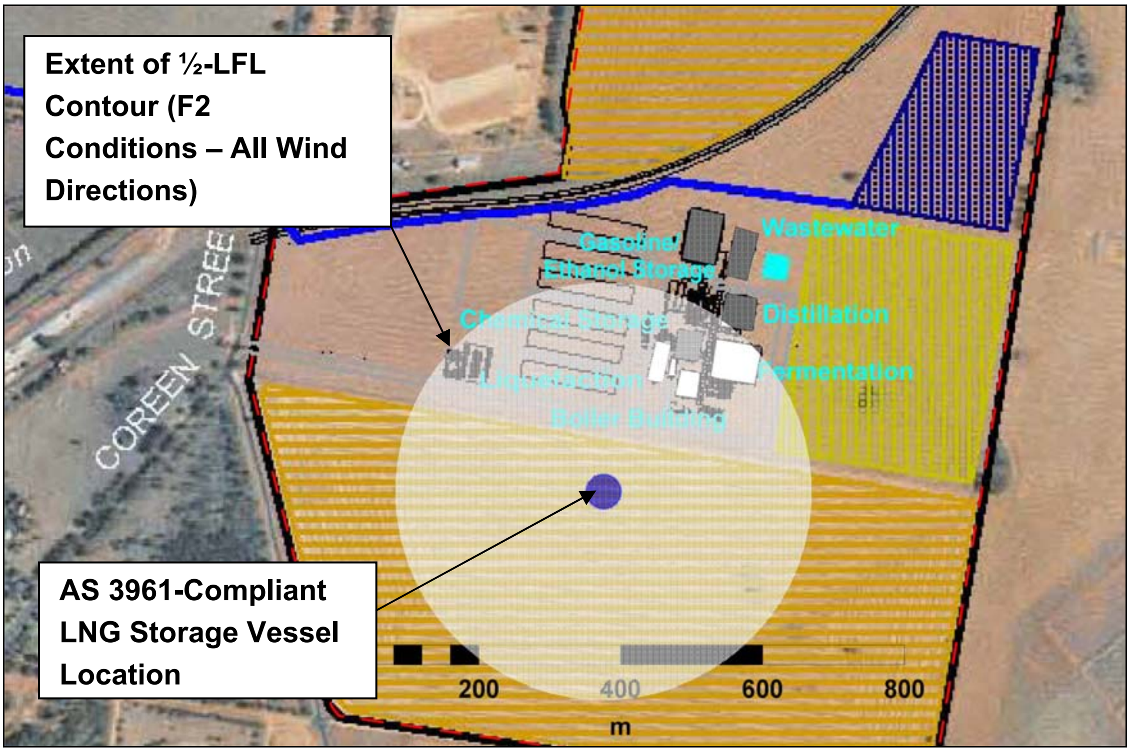
The flash fire (vapour cloud) dimensions summarised in Table 5.5 indicate that the (centroid of the) LNG vessels should be located more than 292 m from the site boundary.

TABLE 5.5: METHANE FLASH FIRE CONSEQUENCE FINDINGS

Weather Class	Cloud Width (m)	Cloud Downwind Distance (m) to ½-LFL	Potential Target of Concern
D5	60	124	Site boundary
F2	186	292	Site boundary

The flash fire contour (F2 Weather Class), superimposed on an acceptable option (satisfying the AS 3961 criteria) for the location of the LNG storage vessels, is shown in Figure 5.2. This figure shows that a methane flash fire (vapour cloud) would not have an offsite impact.

FIGURE 5.2: METHANE FLASH FIRE CONTOUR (LAYOUT PER AS3961 CLAUSE 2.6.2)



5.4. Conclusions

The petrol and ethanol consequence analysis has demonstrated that:

- The 4.7 kW/m^2 (injury) contour remains on site for all fire cases modelled. Therefore, fires would not impact public places beyond the site boundary.
- A full-surface bund fire may have the potential to escalate to other tanks (containing petrol or ethanol) within the storage area, but the resultant fire would not have a greater impact than the full surface bund fire modelled.
- Ethanol and petrol full-surface bund fires would not have the potential to escalate to the LNG vessels, due to large separation distance (> 300m). Conversely, a fire at the LNG vessels would not have the potential to escalate to the ethanol and petrol bulk storage tanks.

The AS 3961 LNG Storage Vessel siting risk assessment has demonstrated that there is sufficient land at the proposed site for the LNG Storage Vessels to be located (as shown in Figure 5.1 and Figure 5.2) such that the consequences of a Maximum Design Spillage would not have the potential to escalate to on-site protected places (e.g. ethanol and petrol bulk storage tanks) and would not have the potential to impact public places beyond the site boundary.

6. FIRE/ EMERGENCY MEASURES AND PROCEDURES

The DGRs for the proposed facility include the following requirement:

… details of fire/ emergency measures and procedures

Although the design of the facility is at a preliminary stage, the following philosophy is to be adopted with respect to design of fire/ emergency measures and procedures:

Design of all systems shall be in compliance with the appropriate Australian Standard.

With respect to fire protection, extensive use will be made of *AS 1940-2004 Storage and handling of flammable and combustible liquids*, which covers the flammable liquids stored at the site (ethanol and petrol). This standard has the following pertinent sections:

- Section 10: Emergency Management;
- Section 11: Fire Protection;
- Appendix J: Fire Exposure Protection; and
- Appendix N: Emergency Planning and Management.

NOTE: *An assessment of the adequacy and survivability of the proposed fire protection system will be undertaken in the Fire Safety Study (see Section 8.2, Recommendation 1) in accordance with NSW DIPNR HIPAP 2 (Ref.11).*

The design of the LNG storage facility (including storage vessel integrity, gas detection and emergency shutdown safeguards) will follow *AS 3961-2005 Storage and handling of liquefied natural gas*.

Other relevant standards include:

- *AS 2444* for the location of fire extinguishers; and
- The Building Code of Australia for fire protection of buildings.
- Classification of hazardous areas for flammable gas and dust will be carried out using *AS 60079.10* and *AS 2430.3*.

7. POTENTIAL IMPACT ON THE BIOPHYSICAL ENVIRONMENT

7.1. Accidental Emissions

Accidental emissions (spills) of ethanol, petrol and other chemicals will be captured in the tank bunds and directed to the site interceptor for recovery.

The LNG storage vessels will be the double-containment (vessel-within-vessel) type; therefore, leaks from the primary containment vessel would be captured by the secondary containment vessel. In the event of an LNG leak outside the secondary vessel, the slope of the floor beneath the vessels would direct the spill to the drainage system.

Therefore, the potential effects of an accidental emission will not affect the long-tem viability of the ecosystem of any sensitive natural environmental areas.

7.2. Polluting Discharge

DoP (Ref.3) indicates that a facility is "potentially offensive" if, "in the absence of any safeguards, the proposal would emit a polluting discharge which would cause a significant level of offence to the people, property or the environment".

An "offensive industry" is one that causes a significant level of offence even when safeguards are implemented. The emission level considered significant is determined by the relevant environmental approval authority.

This PHA has reviewed the 'potentially hazardous' nature of the development. The 'potentially offensive' aspect of the development is covered in detail in the EA (Ref.12).

8. CONCLUSIONS AND RECOMMENDATIONS

8.1. Findings & Conclusions

- The PHA was carried out in accordance with DIPNR guidance: *HIPAP 6* and *Multi-level Risk Assessment*.
- A HAZID review meeting was held between the designers (PDF) and Sherpa to identify potential hazard scenarios, their causes, consequence and safeguards in place in the design.
- The outcome of the HAZID was a set of 7 Major Accidents (MAs) with the potential for offsite impact, which were carried forward for quantification. These were:
  - Ethanol full surface bund fire in the bulk storage area;
  - Petrol full surface bund fire in the bulk storage area;
  - Ethanol spray fire in the distillation process area;
  - Ethanol pool fire at the tank truck loading area;
  - Petrol pool fire at the tank truck loading area;
  - LNG pool fire at the LNG storage vessels/ tanker unloading area; and
  - Unignited LNG pool at storage vessels/ tanker unloading area, leading to evaporation, vapour cloud dispersion and flash fire, if ignited.
- The consequences of the MAs identified were assessed using the proprietary consequence modelling packages *Shell FRED* (Version 4) and BREEZE LFG Fire/ Risk Version 5.0.3 (incorporating DEGADIS). It was found that these events would not have the potential for offsite impact (fatality, injury or offsite escalation) and thus would not have the potential for impact at adjacent public places. Therefore:
  - the offsite individual and societal risk of injury, due to heat radiation, from the development would not exceed the 50 x 10^{-6} per year NSW Land-Use Safety Planning risk criteria for heat radiation injury; and
  - the risk of accident propagation offsite from the development would not exceed the 50 x 10^{-6} per year NSW Land-Use Safety Planning risk criteria for accident propagation.
- The *AS 3961* LNG Storage Vessel siting risk assessment demonstrated that there is sufficient land at the proposed site for the LNG Storage Vessels to be located such that the consequences of a Maximum Design Spillage would not have the potential for escalation to on-site protected places (e.g. ethanol and petrol bulk storage tanks) and would not have the potential to impact public places beyond the site boundary.
- Accidental emissions (spills) of ethanol, petrol and other chemicals will be captured in the tank bunds and directed to the site interceptor for recovery. The LNG storage vessels will be the double-containment (vessel-within-vessel) type;

therefore, leaks from the primary containment vessel would be captured by the secondary containment vessel. In the event of an LNG leak outside the secondary vessel, the slope of the floor beneath the vessels would direct the spill to the drainage system. Therefore, the potential effects of an accidental emission will not affect the long-tem viability of the ecosystem of any sensitive natural environmental areas.

- Whilst there is potential for escalation between the tanks in the Ethanol and Petrol storage area, the consequences would be no worse than the full surface bund fire modelled (found not to have potential for offsite impact).
- Ethanol and petrol full-surface bund fires would not have the potential to escalate to the LNG vessels, due to large separation distance (>300m). Conversely, a fire at the LNG vessels would not have the potential to escalate to the ethanol and petrol bulk storage tanks.
- The development was screened against *SEPP 33* and it was found that a Route Selection Study (Ref.13) may be required due to the high volume of vehicle movements proposed to transport ethanol from the site.

8.2. Recommendations

1. As the design develops the project is required to complete a number of other safety and risk studies in accordance with the NSW Department of Planning Seven Stage Approval Process and as requested by the Director General, viz.:

Project Phase	Safety Study
Design Stage	Hazard and Operability Study
	Final Hazard Analysis (updating this PHA)
	Fire Safety Study
	Emergency Plan
Construction/Commissioning Stage	Construction Safety Study
Operational Stage	Safety Management System
	Independent Hazard Audit

2. It is recommended that the project develop a Safety Management System in accordance with HIPAP 9 (Ref.6).
3. It is recommended that the project develop an Emergency Plan in accordance with HIPAP 1 (Ref.7).
4. It is recommended that assumptions made in this report be re-checked when more detailed information is available; e.g. the distance from the Ethanol Storage area to the site boundary should be checked to ensure that the separation distance of greater than 85m is maintained such that the consequences of a fire in this area remain on site (see Section 5.2).
5. Subject to the Director General's requirements, a Route Selection Study (Ref.5) may be required due to the volume of vehicle movements proposed to transport the produced ethanol and the quantity of LNG delivered to the site per delivery.

6. This PHA (Revision A) selected a location for the LNG facility based on the outcome of the risk-based review against *AS 3961-2005 Clause 2.6.3*. Should the detailed design require another location to be chosen, a 292 m separation distance should be maintained between the vessel and the site boundary, as discussed in Section 5.3 of this report (if the quantity of stored LNG exceeds 100 m^3). Should the final design require an LNG storage capacity less than 100 m^3, vessel location and spacing can be determined from *AS 3961-2005 Clause 2.6.3 (i.e. rather than Clause 2.6.2).*

7. The design of the floor grade beneath the LNG vessels must ensure that any LNG spills will:

   - drain away from the LNG vessels (and other stores of flammable, combustible or hazardous goods) to a safe location; and
   - not enter any open drains, creeks, waterways or other feature where water may be present at any time.

8. It is recommended that the latest revisions of the appropriate Australian Standards (including those identified in this document, viz.: AS 1940, AS 3961, Building Code of Australia, AS60079.10) are consulted during the Design Stage.

APPENDIX 1. HAZARD IDENTIFICATION WORD DIAGRAM

ID	Plant Area	Guide Word	Risk Event	Causes	Controls - Prevention	Controls - Detection / Mitigation	Carried Forward	Actions	By
Main Process (Ethanol Production)									
1	Grain Receiving and Storage	Fire / explosion (internal to process)	Dust explosion	Dust generated and ignition source found	Dust generation limited. No ignition sources in silo, all electrical/mechanical ignition sources outside.	None.	No		
2	Grain Receiving and Storage	Fire / explosion (internal to process)	Incipient fire within grain store. Possible toxic plume generated due to pesticides used to protect grain.	Ignition source Contamination of grain, eg cigarette butt.	Quality Assurance of grain received	None, although structural integrity of silo is such that fire is unlikely to cause damage.	No		
3	Grain Receiving and Storage	Exposure to personnel	Worker trapped within grain silo	Bridging and subsequent release of grain.	Confined space working procedures	When working in confined spaces workers will comply with confined space rules (harness, buddy, ensuring fresh air etc).	No		
4	Milling	Fire / explosion (internal to process)	Dust explosion	Hammer in hammer mill detached and impacts other metal parts causing ignition of dusty atmosphere.	Mechanical integrity of hammer. Dust extract system removes dust as far as possible.	Hammer mill designed to contain dust explosion. If explosion at dust collector, explosion vents prevent destruction.	No		
5	Milling	Fire / explosion (internal to process)	Dust explosion	Static, especially in dust collection system.	All equipment bonded to earthing mat. Dust collection bags have carbon fibres to prevent static build-up.	None	No		
6	Milling	Fire / explosion (internal to process)	Fire in grain elevator	Friction of elevator belts causes ignition of grain.	Regular inspection of elevators to minimise friction.	Detection system alerts operators and then shuts down system if smoke is detected.	No		

ID	Plant Area	Guide Word	Risk Event	Causes	Controls - Prevention	Controls - Detection / Mitigation	Carried Forward	Actions	By
7	Milling	Fire / explosion (following release)	Dust explosion	Primary explosion causes loss of containment of ignited dust and produces secondary explosion.	Hammer mill designed to contain explosion (volume within is small). Good housekeeping should minimise dust that may become fuel for secondary explosion.	Equipment installed in an 'open' structure allowing free flow of air and no confinement. Overpressure generation is therefore minimised.	No	Design should minimise horizontal surfaces, and those that exist should be readily accessible for cleaning. Consider vacuum cleaning system.	AEL
8	Milling	Fire / explosion (following release)	Dust explosion	Primary explosion causes loss of containment of ignited dust and produces secondary explosion.	Hammer mill designed to contain explosion (volume within is small). Good housekeeping should minimise dust that may become fuel for secondary explosion.	Equipment installed in an 'open' structure allowing free flow of air and no confinement. Overpressure generation is therefore minimised.	No	Ensure that procedures are in place to minimise dust on floor/ external equipment surfaces especially in milling area.	AEL
9	Liquefaction	Harmful exposure (acute or chronic)	Steam (7 bar) loss of containment at steam cooker. Local jet of steam may impact personnel.	Mechanical failure of equipment	Integrity of equipment. Jet cooker is designed for this service.		No	Ensure that shutdown system on boiler can detect and shutdown for this scenario.	PDF
10	Liquefaction	Harmful exposure (acute or chronic)	Caustic loss of containment, eg pump seal failure and possible impact to personnel.	Mechanical failure of equipment	Integrity of equipment. Caustic system is designed for this service.		No	Ensure that location of caustic pump minimises the risk of caustic impacting personnel.	PDF
11	Fermentation	General Discussion	Loss of containment of a fermentation tank (approx 2500m3). Large liquid release.	External event such as earthquake.	Tanks designed beyond requirements of AS 1692, and designed for earthquake.	Liquid would be contained onsite due to local kerbing and also distance from site boundary.	No		

ID	Plant Area	Guide Word	Risk Event	Causes	Controls - Prevention	Controls - Detection / Mitigation	Carried Forward	Actions	By
12	Distillation	Fire / explosion (following release)	Loss of containment of hot ethanol (~70C) leading to possible pool/spray fire on ignition.	Pump seal leak, flange leak etc.	All equipment designed to appropriate standard for pressures and temperature in process. Area classified as Zone 1, and electrical equipment rated as such. All equipment earthed and bonded to grid to prevent static build-up.	Vapour detection system will alarm at 25% LFL, and shutdown at 50% LFL. Shutdown includes cutting power to motors as well as closing valves. Emergency cooling of critical condensers to reduce pressure. Distillation section remote from plant boundary, and surrounded by kerbing to prevent liquid spread.	Yes		
13	Distillation	Fire / explosion (internal to process)	Leak into the vacuum distillation column leading to internal explosion on ignition.	Flange/seal leak	Mechanical integrity of equipment.	No ignition sources inside the process equipment. Temperature inside column below the auto-ignition temperature of Ethanol (363ºC) High pressure detection and shutdown of column.	No		
14	Ethanol Storage	Fire / explosion (following release)	Loss of containment of ethanol in storage area.	Flange leak, overfill	Tanks designed to AS1940, including overfill protection (independent shut-off on high level). Vent condenser minimises ethanol evolution from tank. Pumps outside bund (reduces leak sources and ignition sources).	Fire detection and firewater/ foam/deluge system designed in accordance with AS1940.	Yes		

ID	Plant Area	Guide Word	Risk Event	Causes	Controls - Prevention	Controls - Detection / Mitigation	Carried Forward	Actions	By
15	Petrol Storage	Fire / explosion (following release)	Loss of containment of petrol in storage area.	Flange leak, overfill	Tanks designed to AS1940. Pumps outside bund (reduces leak sources and ignition sources).	Fire detection and firewater/ foam/deluge system designed in accordance with AS1940. Tanks have bunds to contain spilled fluid.	Yes		
16	Ethanol loading	Fire / explosion (following release)	Loss of containment while loading ethanol to road tanker.	Hose failure, hose misconnection, pump seal failure.	Hoses have dry-break couplings. Equipment designed for purpose to relevant standards.	Fire detection and firewater/ foam/deluge system designed in accordance with AS1940. Bunding of tanks, loading bay will have spill containment system.	Yes		
17	Petrol Loading	Fire / explosion (following release)	Loss of containment while loading Petrol to road tanker.	Hose failure, hose misconnection, pump seal failure.	Hoses have dry-break couplings. Equipment designed for purpose to relevant standards.	Fire detection and firewater/ foam/deluge system designed in accordance with AS1940. Bunding of tanks, loading bay will have spill containment system.	Yes		
17	Chemical Storage	Harmful exposure (acute or chronic)	Mixing of incompatible chemicals leading to overheating and tank failure, or evolution of toxic gas.	Road tanker unloaded into wrong storage tank.	Chemical tanks will be in different bunds, and clearly placarded as specified in the relevant AS and the NSW DG Regulations.	None identified.	No	Ensure that it is extremely difficult to unload incorrect chemicals into a bulk tank, eg by different hose couplings and site layout.	PDF

ID	Plant Area	Guide Word	Risk Event	Causes	Controls - Prevention	Controls - Detection / Mitigation	Carried Forward	Actions	By
18	Tanker movements	General Discussion	Tanker accident on site.	Driver confusion. Driver fatigue	None identified.	None identified.	No	Ensure that road tankers are strictly controlled within the site, and one way system is used to give smooth traffic flow and reduce likelihood of vehicle impacts.	PDF
LNG Storage Vessels **(NOTE: The HAZID does not include security breaches, vandalism or other deliberate acts which could lead to a loss of containment and/or fire.)**									
19	**LNG Tanker Unloading**	Fire / explosion (following release) Harmful exposure (acute or chronic)	Liquid or vapour leak during transfer from road tanker to bulk storage Potential for driver injury (cold burns). Potential pool and jet/ spray fire if ignited immediately. Pool evaporation and gas cloud: potential flash fire upon delayed ignition. **NOTE:** vapour cloud deflagration (explosion) is not likely due to the low reactivity of methane and the low-level of equipment congestion in the area. Any overpressure produced would be within the flash cloud and would not be likely to lead to escalation.	Instrument fitting leak	Protected from mechanical impact: - fittings located close to vessel; - no vehicle access to storage area.	Gas detectors: emergency auto-shutdown on confirmed gas Ignition control. Fusible loops on vessels (fire detection). Emergency shutdown. **NOTE:** Applying firewater or foam to LNG pool spill/fire is not appropriate - see Rapid Phase Transition.	Yes	**GLOBAL ACTION APPLIES TO ALL ITEMS BELOW (19 – 31):** The final design of the LNG Storage Facility should include the controls listed in this HAZID (or a suitably equivalent safeguarding measure).	AEL & PDF
				Hose coupling error	Driver training. Coupling design provides indication that coupling achieved (clicks-together) .		Yes		
				Hose tear	Double-containment (hose-in-hose) design: simultaneous failure of both internal and external hoses is unlikely. Not a credible leak scenario.		No, not a credible scenario.		
				Flange failure	Soft-metal-type: minimise potential for leak and leak-hole size.		Yes		
				Valve gland leak	Material selection. Preventative maintenance.		Yes		
				Pump seal leak	Material selection. Preventative maintenance.		Yes		

ID	Plant Area	Guide Word	Risk Event	Causes	Controls - Prevention	Controls - Detection / Mitigation	Carried Forward	Actions	By
				Pump casing failure	Material selection. Preventative maintenance.		Yes		
				Pipe failure/ rupture	Material selection. Preventative maintenance.		Yes		
				Overfill	Monitored by PLC - tanker connection area will be provided with a display indicating vessel pressure and level. The PLC will be provided with interlocks to: - prevent the driver from initiating transfer into a full vessel; and - provide an override against overfilling the vessels beyond the requirement of AS 3961 Clause 3.2.3 (via instrumented ΔP level monitoring). Manual level monitoring (ΔP gauge) is also provided for the drivers' use.		Yes		
				Vehicle impact with LNG pipework on approach to vessels	Driver training. Low speed limits on-site. Open area: good visibility. Bollards and fencing provided around vessel compound.		Yes		
				Tanker drive-away whilst hose connected	Driver training. Disconnection procedures. Tanker brake interlock. Break-away coupling will minimise leak.		Yes		
20	**LNG Tanker Unloading**	Fire / explosion (following release) Harmful exposure (acute or	Rapid phase transition	Water in fill lines prior to LNG transfer – potential for rapid flashing of liquid on contact with	Driver training. Hose connection procedures include water-freeing of hose.	Driver inspection. Procedures. Gas detectors: emergency auto-shutdown on confirmed gas.	**No. This scenario is unlikely to lead to off-site impact.**		

ID	Plant Area	Guide Word	Risk Event	Causes	Controls - Prevention	Controls - Detection / Mitigation	Carried Forward	Actions	By
		chronic)		water					
21	**LNG Storage Vessels**	Fire / explosion (following release) Harmful exposure (acute or chronic)	Liquid or vapour leak from storage (including all equipment up to vaporisers) Potential pool and jet/ spray fire if ignited immediately. Pool evaporation and gas cloud: potential flash fire upon delayed ignition. **NOTE:** vapour cloud deflagration (explosion) is not likely to occur due to the low reactivity of methane and the low-level of equipment congestion in the area. Any overpressure produced would be within the flash cloud and would not be likely to lead to escalation.	Instrument fitting leak (without restriction orifice)	Protected from mechanical impact: - fittings located close to vessel; - no vehicle access to storage area.	Gas detectors: emergency auto-shutdown on confirmed gas. Ignition control. Fusible loops on vessels (fire detection). Emergency shutdown. NOTE: Applying firewater or foam to LNG pool spill/fire is not appropriate - see Rapid Phase Transition.	Yes		
				Instrument fitting leak (with restriction orifice)			Yes		
				Flange failure	Soft-metal-type: minimise potential for leak and leak-hole size.		Yes		
				Valve gland leak	Material selection. Preventative maintenance.		Yes		
				Pipe failure/ rupture	Material selection. Preventative maintenance.		Yes		
				Vehicle impact with LNG pipework	Driver training. Low speed limits on-site. Open area: good visibility. Bollards and fencing provided around vessel compound.		Yes		
22	**LNG Storage Vessels**	Fire / explosion (following release) Harmful exposure (acute or chronic)	PRV lifts to relieve vessel pressure - potential for flammable vapour cloud formation and flash fire (if ignited).	Vessel remains idle for extended period of time; weathering may lead to roll-over and potential venting via PRV	Low probability of vessels remaining idle for long periods of time (estimates indicate that 3 daily LNG tanker deliveries will be required). The mixing from continuous filling and emptying makes stratification highly unlikely. The probability of a 'hot liquid under pressure' is low, since there would not be a large difference in pressure between the top and bottom of the vessel.	PLC alarm - high pressure. Gas detectors: emergency auto-shutdown on confirmed gas. Ignition control. Fusible loops on vessels (fire detection and ESD).	No, not a credible loss of containment scenario.		

ID	Plant Area	Guide Word	Risk Event	Causes	Controls - Prevention	Controls - Detection / Mitigation	Carried Forward	Actions	By
23	**LNG Storage Vessels**	Fire / explosion (following release) Harmful exposure (acute or chronic)	Overpressure of internal vessel Potential failure of internal vessel (if safeguards fail to protect) and leak into external vessel A liquid LNG leak into the annular space between inner and outer vessels will quickly vaporise and blow the vacuum space "pop-off" valves. The carbon steel outer skin may be subjected to low temperatures (leading to cold embrittlement).	LNG vapour pressure increase due to: - unusually high ambient temperatures - fire impingement on vessel - vessel/s idle for long period Power station not drawing fuel (viz. leading to all vessels idling)	Process control and safeguarding.	Gas detectors. Pressure monitoring inside vessel. PLC alarm on PRV activation. PLC alarm on low vessel pressure . Outer vessel vacuum space "pop-off" valves. Load-bearing paths inside the annular space are not made of carbon steel and won't be vulnerable. Load-bearing paths outside the vessels, viz. the pedestals, will be sufficiently remote from the cold to continue to perform as designed.	Yes		
24	**LNG Storage Vessels**	Escalation	Potential cold embrittlement of vessel supports leading to vessel damage.	LNG liquid pool beneath LNG storage vessels	The grade beneath the vessels will slope away from the ethanol plant (and petrol and ethanol tanks) and prevent pooling below the vessels. **NOTE:** Project to ensure that drained LNG does not enter any drains, creek beds, etc. where water can be present.	Gas detectors: emergency auto-shutdown on confirmed gas. Vessels to be designed/ constructed to ASME VIII. The vessels will be mounted on concrete foundations and the plinths will provide freeboard between the vessel and ground. Load-bearing paths outside the vessels, the pedestals, will be sufficiently remote from the cold to continue to	No, given the level of safeguarding. An LNG spill has been carried forward.		

ID	Plant Area	Guide Word	Risk Event	Causes	Controls - Prevention	Controls - Detection / Mitigation	Carried Forward	Actions	By
						perform as designed. External supports will comply with AS3961 (Clause 3.4.3), requiring lagging (concrete) of the steel supports to give adequate resistance to fire, but will also provide protection from low temperatures.			
25	**LNG Storage Vessels**	Escalation	Potential vessel damage. Prolonged fire impingement may lead to failure of the outer skin (external vessel), potentially leading to a loss of vacuum in the annular space.	LNG pool/ jet fire impinging on LNG vessel and/or vessel supports.	The grade beneath the vessels will slope away from the ethanol plant (and petrol and ethanol tanks) and prevent pooling below the vessels.	Initial vapour releases will be detected by gas detectors: emergency auto-shutdown on confirmed gas. Vessels to be designed/ constructed to ASME VIII. The vessels will be mounted on concrete foundations and the plinths will provide freeboard between the vessel and ground. The insulation between inner/outer vessels will largely remain in place if the outer skin (external vessel) fails. The inner stainless steel pressure vessel will continue to perform as designed, protected from the heat by the insulation, but with a higher than	No, given the level of safeguarding. An LNG fire has been carried forward.		

ID	Plant Area	Guide Word	Risk Event	Causes	Controls - Prevention	Controls - Detection / Mitigation	Carried Forward	Actions	By
						normal boil-off (potential PRV lifting). External supports will comply with AS3961 (Clause 3.4.3), requiring lagging (concrete) of the steel supports to give adequate resistance to fire.			
26	**LNG Storage Vessels**	Escalation	Potential escalation to other bulk storage tanks.	LNG pool/ jet fire impinging (or heat radiation impact) on ethanol and petrol storage tanks.	The grade beneath the vessels will slope away from the ethanol plant (and ethanol/petrol tanks) and prevent pooling below the vessels. (see also leak prevention measures above) The LNG storage facility will be segregated from the bulk stores of ethanol and petrol.	Fire detection in ethanol/ petrol storage compound will initiate alarm and start firewater system.	Yes		
27	**Vapourisers**	Fire / explosion (following release) Harmful exposure (acute or chronic)	Vapour leak from vapourisers and downstream equipment (including gas pressure regulator/s). Potential jet fire if ignited immediately. Potential cloud formation and flash fire upon delayed ignition. [Note: vapour cloud deflagration (explosion) is not likely to occur	Instrument fitting leak	Protected from mechanical impact: - fittings located close to vessel; - no vehicle access to storage area.	Gas detectors: emergency auto-shutdown on confirmed gas. Ignition control. Fusible loops on vessels (fire detection). Emergency shutdown.	Yes		
				Flange failure	Soft-metal-type: minimise potential for leak and leak-hole size.		Yes		
				Valve gland leak	Material selection. Preventative maintenance.		Yes		
				Pipe failure/ rupture	Material selection. Preventative maintenance.		Yes		

ID	Plant Area	Guide Word	Risk Event	Causes	Controls - Prevention	Controls - Detection / Mitigation	Carried Forward	Actions	By
			due to the low reactivity of methane and the low-level of equipment congestion in the area. Any overpressure produced would be within the flash cloud and would not be likely to lead to escalation]	Vehicle impact with vapour pipework	Driver training. Low speed limits on-site. Open area: good visibility. Bollards and fencing provided around vessel compound.		Yes		
28	**Vapourisers**	Fire / explosion (following release) Harmful exposure (acute or chronic)	No vapourisation and liquid breakthrough to downstream pipework Cold liquid causes embrittlement of carbon steel pipework leading to potential failure and leak of liquid. Potential pool and jet/ spray fire if ignited immediately. Pool evaporation and gas cloud: potential flash fire upon delayed ignition.	Vapouriser performance degrades/ fails	Process control and safeguarding.	Vapouriser performance is more likely to degrade slowly resulting in low vapour temperatures followed by small quantities of liquid carry-over. Ignition control. Fusible loops on vessels (fire detection). Emergency shutdown.	Yes		
29	LNG Storage Compound	**External Hazards**	External fire (non-LNG related) inside/ outside LNG vessel compound. Potential escalation to LNG vessel/s or vessel supports leading to vessel damage. Prolonged fire impingement, whilst unlikely due to the separation distance, may lead to failure of the outer skin (external vessel), potentially leading to a loss of vacuum in the annular space.	Ignition of a non-LNG combustible/ flammable material outside/ inside the vessel compound	There will be no combustible/ flammable materials (other than LNG) stored within the vessel compound. Large separation distance between LNG vessels and bulk petrol and ethanol storage tanks.	Fire detection in tank storage compound will initiate alarm and start firewater system. Fusible loops provided on vessels will initiate alarm and ESD.	Yes (as part of the main ethanol plant HAZID) to investigate the potential for escalation to the LNG storage vessels.		

ID	Plant Area	Guide Word	Risk Event	Causes	Controls - Prevention	Controls - Detection / Mitigation	Carried Forward	Actions	By
30	LNG Storage Compound	Extreme weather	Failure of vessel/ pipework Potential jet fire if ignited immediately. Potential cloud formation and flash fire upon delayed ignition. [Note: vapour cloud deflagration (explosion) is not likely to occur due to the low reactivity of methane and the low-level of equipment congestion in the area. Any overpressure produced would be within the flash cloud and would not be likely to lead to escalation]	Very strong wind, flooding, extreme ambient temperatures	The basis of design will consider loading due to cyclone/ high wind.	Gas detectors: emergency auto-shutdown on confirmed gas Ignition control. Fusible loops on vessels (fire detection).	Yes		
31	**Creeks, Waterways, Water Drains**	Rapid phase transition	Rapid flashing of liquid resulting in pressure increase (due to 600 x expansion of liquid to gas). The risk of Rapid Phase Transition (RPT) is greater if water is spilled onto LNG. In the case of LNG spilled onto water, the water would freeze and provide insulation between the LNG pool and the water - thereby reducing the rate at which heat is extracted from the water and, consequently, the risk of RPT. However, if the body of water is turbulent (e.g. creek), the splashing could lead to RPT.	LNG spill (as described above) enters a creek, waterway, drain or other area where water may be present.	Site drainage to be segregated from water drains. Grading beneath vessels will ensure that LNG spills are directed away from creeks, waterways, drains and other areas where water may be present. General site house-keeping and maintenance to prevent pooling (or other accumulation) of water near potential leak points on the LNG storage vessels and associated equipment.	Operator inspections. Gas detectors will detect spill and initiate emergency shutdown on confirmed gas.	Yes		

APPENDIX 2. REVIEW OF HAZARDOUS SUBSTANCES PROPERTIES

A 2.1. Ethanol

Ethanol is a Class 3 flammable liquid which ignites readily when exposed to an ignition source. Detailed properties are given below.

TABLE 8.1: ETHANOL PROPERTIES

Property	**unit**	**Value**
Formula		C_2H_5OH
Boiling point	^oC	78.3
Vapour density (cf air = 1)		1.6
Liquid density (cf water = 1)		0.79
Heat of combustion	MJ/kg	0.837
Flashpoint	^oC	13-18
Lower Flammable Limit (LFL)	vol%	3.3
Upper Flammable Limit (UFL)	vol%	19

TABLE 8.2: HAZARDOUS PROPERTIES & EMERGENCY ADVICE

Incident	**Hazardous Properties**
Release as Vapour	Irritating to eyes, nose and throat. Move to fresh air.
Release as Liquid	Not harmful.
Fire	FLAMMABLE. Flashback along vapour trail may occur. Vapour may explode if ignited in an enclosed area. Extinguish with dry chemical, alcohol foam, or carbon dioxide. Water may be ineffective on fire. Cool exposed containers with water.

A 2.2. Petrol

Petrol is a Class 3 flammable liquid; detailed properties are given below.

TABLE 8.3: PETROL PROPERTIES

Property	**unit**	**Value**
Formula		N/A
Boiling point	^oC	60-199
Vapour density (cf air = 1)		3.4
Liquid density (cf water = 1)		0.732
Heat of combustion	MJ/kg	43.5
Flashpoint	^oC	-38
Lower Flammable Limit (LFL)	vol%	1.4
Upper Flammable Limit (UFL)	vol%	7.4

TABLE 8.4: HAZARDOUS PROPERTIES & EMERGENCY ADVICE

Incident	Hazardous Properties
Release as Vapour	Irritating to eyes, nose and throat. If inhaled, will cause dizziness, headache, difficult breathing or loss of consciousness. Move to fresh air. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen.
Release as Liquid	Irritating to skin and eyes. If swallowed, will cause nausea or vomiting. Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk. DO NOT INDUCE VOMITING.
Fire	Flashback along vapour trail may occur. Vapour may explode if ignited in an enclosed area. Extinguish with dry chemical, foam, or carbon dioxide. Water may be ineffective on fire. Cool exposed containers with water.

A 2.3. LNG

The hazardous properties of LNG are:

- Its vapour is flammable;
- Its vapour is heavier than air at vapour temperatures below about -110^{o}C; and
- The liquid is cryogenic, requiring special materials of construction due to the intense cold and special personal protection equipment to prevent cold burns.

Other characteristics of LNG are given in Table 8.5. It should be noted that natural gas vapour at ambient conditions (predominantly methane) is lighter than air and so will tend to rise and disperse into the atmosphere.

TABLE 8.5: PHYSICAL PROPERTIES OF LNG

Characteristic	Value
Boiling Point	-161.4^{o}C at 101.3kPa
Liquid Density	415 kg/m^3 at boiling point
Vapour Density	1.64 kg/m^3 at boiling point
Lower Flammability Limit	5% (v/v)
Upper Flammability Limit	15% (v/v)
Heat of Vaporisation	511 kJ/ kg at 101.3kPa
Expansion Ratio	1L liquid at boiling point = 590L vapour at STP

A 2.4. Sulphuric Acid (94%)

Concentrated sulphuric acid is a Class 8 material, which is highly corrosive. Detailed properties are given below.

TABLE 8.6: SULPHURIC ACID PROPERTIES

Property	unit	Value
Formula		H_2SO_4
Boiling point	^oC	340
Vapour density (cf air = 1)		N/A
Liquid density (cf water = 1)		1.84
Heat of combustion	MJ/kg	N/A
Flashpoint	^oC	Not Flammable
Lower Flammable Limit (LFL)	vol%	N/A
Upper Flammable Limit (UFL)	vol%	N/A

TABLE 8.7: HAZARDOUS PROPERTIES & EMERGENCY ADVICE

Incident	Hazardous Properties
Release as Mist	Irritating to eyes, nose and throat. If inhaled, will cause coughing, difficult breathing, or loss of consciousness. Move to fresh air. IF IN EYES, hold eyelids open and flush with plenty of water. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen.
Release as Liquid	Will burn skin and eyes. Harmful if swallowed. Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk. DO NOT INDUCE VOMITING.
Fire	Not flammable. Poisonous gas may be produced in fire. Extinguish with dry chemical or carbon dioxide.

A 2.5. Sodium Hydroxide (20%)

Sodium Hydroxide is a Class 8 material, and is corrosive. Detailed properties are given below.

TABLE 8.8: SODIUM HYDROXIDE PROPERTIES

Property	unit	Value
Formula		NaOH
Boiling point	^oC	Not available
Vapour density (cf air = 1)		N/A
Liquid density (cf water = 1)		1.22

Property	unit	Value
Heat of combustion	MJ/kg	N/A
Flashpoint	^oC	Not Flammable
Lower Flammable Limit (LFL)	vol%	N/A
Upper Flammable Limit (UFL)	vol%	N/A

TABLE 8.9: HAZARDOUS PROPERTIES & EMERGENCY ADVICE

Incident	Hazardous Properties
Release as Mist	N/A
Release as Liquid	POISONOUS IF SWALLOWED Extremely corrosive to eyes, skin, nose, throat, and upper respiratory tract. IF IN EYES: hold eyelids open, flush with running water for at least 15 minutes. Remove contaminated clothing and shoes, flush affected areas with plenty of running water for at least 15 minutes. IF SWALLOWED and victim is CONSCIOUS: have victim drink water, milk, dilute vinegar, lemon juice, or olive oil to dilute the material. IF SWALLOWED and victim is UNCONSCIOUS OR HAVING CONVULSIONS: do nothing except keep victim warm. DO NOT INDUCE VOMITING
Fire	Non-combustible

A 2.6. Nitric Acid (20%)

Nitric Acid is a Class 8 material, and is corrosive. Detailed properties are given below.

TABLE 8.10: NITRIC ACID PROPERTIES

Property	unit	Value
Formula		HNO_3
Boiling point	^oC	88.9
Vapour density (cf air = 1)		N/A
Liquid density (cf water = 1)		1.49
Heat of combustion	MJ/kg	N/A
Flashpoint	^oC	Not Flammable
Lower Flammable Limit (LFL)	vol%	N/A
Upper Flammable Limit (UFL)	vol%	N/A

TABLE 8.11: HAZARDOUS PROPERTIES & EMERGENCY ADVICE

Incident	Hazardous Properties
Release as Vapour	Will burn eyes, nose and throat. If inhaled, will cause difficult breathing or loss of consciousness. Move to fresh air. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen.
Release as Liquid	Will burn skin and eyes. Harmful if swallowed. Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk. DO NOT INDUCE VOMITING.
Fire	Not flammable. May cause fire on contact with combustibles. Flammable gas may be formed on contact with metals. Poisonous gases are produced when heated. Wear chemical protective suit with self-contained breathing apparatus. Cool exposed containers with water.

A 2.7. Aqueous Ammonia (25%)

Aqueous Ammonia is a Class 8 material, and is corrosive. Detailed properties are given below.

TABLE 8.12: AQUEOUS AMMONIA PROPERTIES

Property	unit	Value
Formula		NH_3
Boiling point	^oC	N/A
Vapour density (cf air = 1)		N/A
Liquid density (cf water = 1)		0.89
Heat of combustion	MJ/kg	N/A
Flashpoint	^oC	Not Flammable
Lower Flammable Limit (LFL)	vol%	N/A
Upper Flammable Limit (UFL)	vol%	N/A

TABLE 8.13: HAZARDOUS PROPERTIES & EMERGENCY ADVICE

Incident	Hazardous Properties
Release as Vapour	Irritating to skin, eyes, nose and throat. If inhaled, will cause nausea, vomiting, difficult breathing, or loss of consciousness. Move to fresh air. IF IN EYES, hold eyelids open and flush with plenty of water. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen.
Release as Liquid	Will burn skin and eyes. Harmful is swallowed. Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk.
Fire	

A 2.8. Urea

Urea is not classified in the ADG Code. It is not harmful, but may be combustible in solid pellet form.

A 2.9. Grain

Although not classified as a dangerous good, grain does have hazardous properties. It is prone forming dust which can explode violently. In the US from 1988 to 1998 there were 129 reported grain dust explosions; 64 were in grain elevators, 48 were in grain milling facilities (Ref 14).

Another hazardous situation that could present itself may be an incipient fire within the grain silo. This may then lead to either release of toxic fumes, or initiate an explosion.

A 2.10. Steam

Steam is used to heat the vacuum distillation column. It is generated in boilers with a maximum temperature of 180^{o}C and a pressure of 7 bar.

APPENDIX 3. CONSEQUENCE ANALYSIS DETAILS

P2

Scenario Summary

Scenario

Scenario = P2
Fluid = Gasoline

Pool

Diameter = 11.3 m
Surface elevation = 0 m

Weather

Ambient conditions

Temperature = 20 °C
Relative humidity = 70 %
Wind speed = 5 m/s
Direction wind is going to = 0 deg
(measured clockwise from North)

Atmospheric stability conditions

Define by = Pasquill class
Pasquill class = D Neutral

Thermal radiation

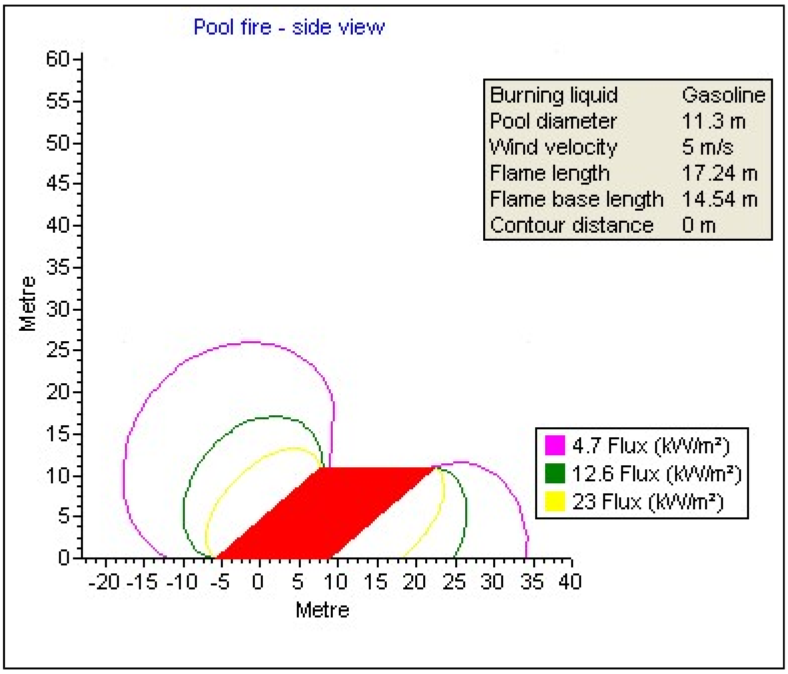
Radiation contours = 4.7, 12.6, 23 kW/m^2
Height at which plan view contours to be plotted = 1.5 m
Cross flame distance at which side view contours to be plotted = 0 m

Pool Fire

Pool Fire Summary

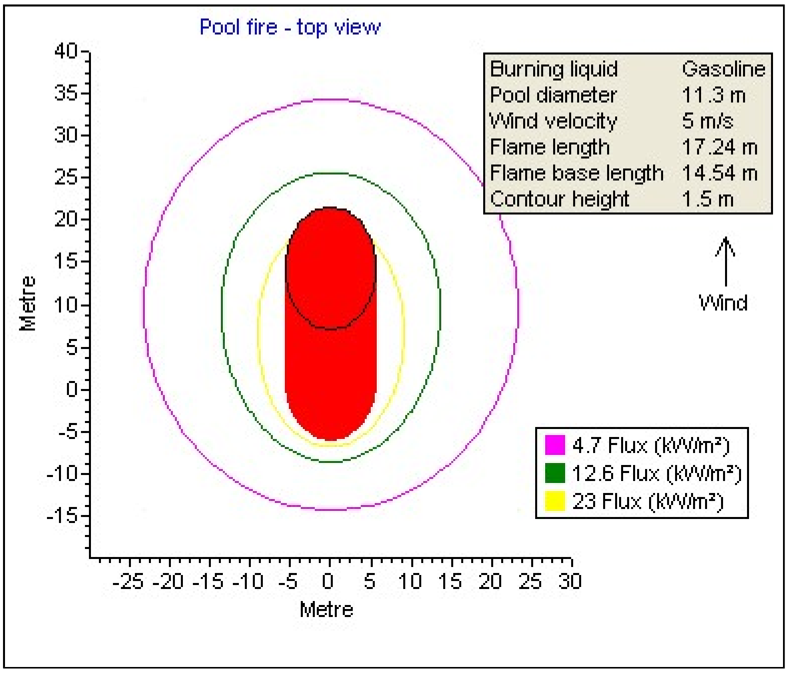
Flame length = 17.24 m
Flame angle from vertical = 50.56 deg
Flame base length = 14.54 m
Surface emissive power = 58.76 kW/m²

Side view



Raw plot data

Top view



Raw plot data

E2

Scenario Summary

Scenario

Scenario = E2
Fluid = Ethanol

Pool

Diameter = 28.2 m
Surface elevation = 0 m

Weather

Ambient conditions

Temperature = 20 °C
Relative humidity = 70 %
Wind speed = 5 m/s
Direction wind is going to = 0 deg
(measured clockwise from North)

Atmospheric stability conditions

Define by = Pasquill class
Pasquill class = D Neutral

Thermal radiation

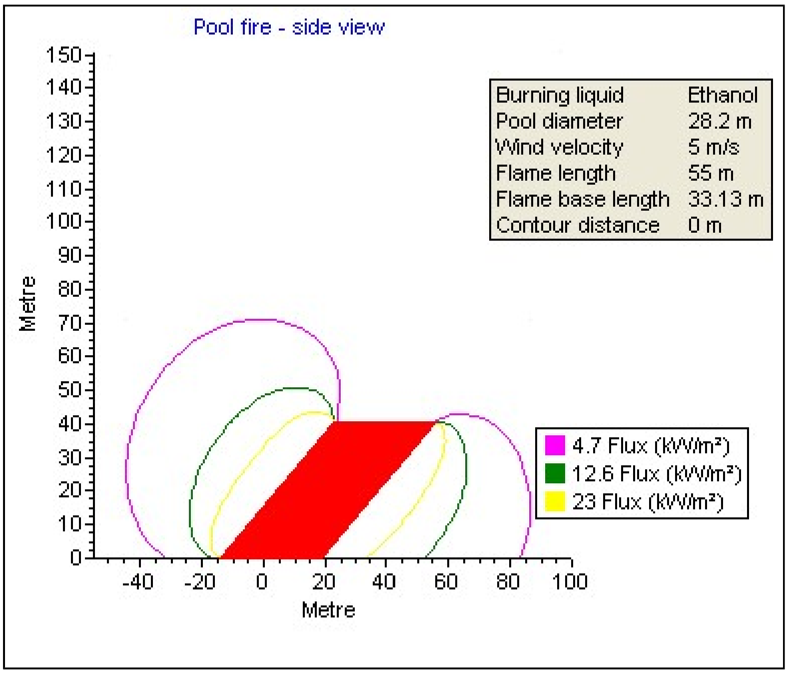
Radiation contours = 4.7, 12.6, 23 kW/m²
Height at which plan view contours to be plotted = 1.5 m
Cross flame distance at which side view contours to be plotted = 0 m

Pool Fire

Pool Fire Summary

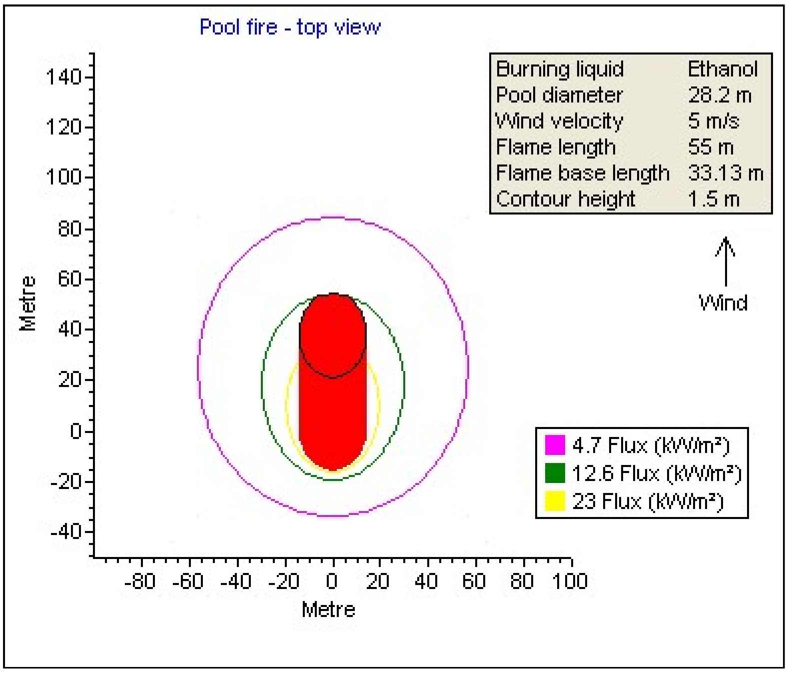
Flame length = 55 m
Flame angle from vertical = 42.19 deg
Flame base length = 33.13 m
Surface emissive power = 51.54 kW/m²

Side view



Raw plot data

Top view



Raw plot data

P1

Scenario Summary

Scenario

Scenario = P1
Fluid = Gasoline

Trench

Width = 5 m
Length = 20 m
Angle from north = 90 deg

Weather

Ambient conditions

Temperature = 20 °C
Relative humidity = 70 %
Wind speed = 5 m/s
Direction wind is going to = 0 deg
(measured clockwise from North)

Atmospheric stability conditions

Define by = Pasquill class
Pasquill class = D Neutral

Thermal radiation

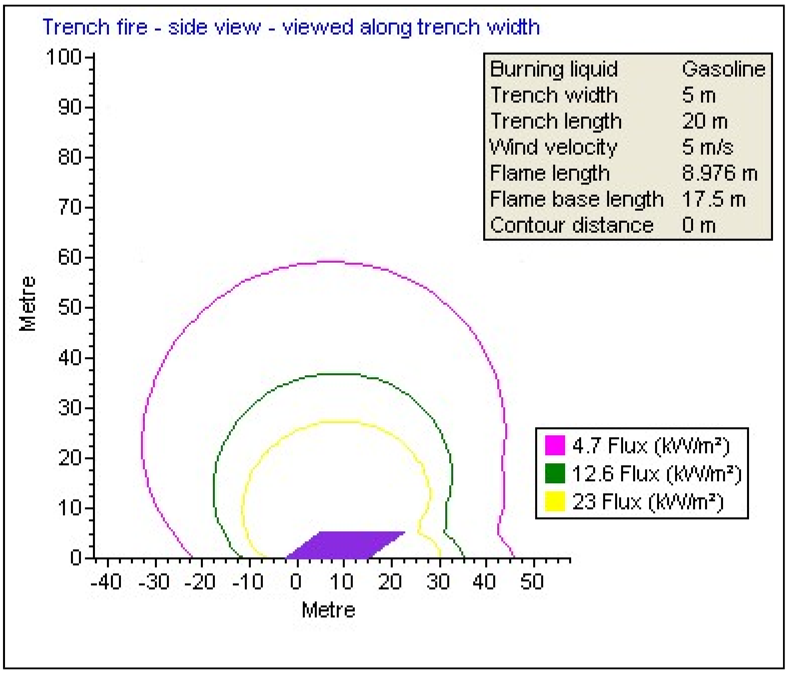
Radiation contours = 4.7, 12.6, 23 kW/m²
Height at which plan view contours to be plotted = 1.5 m
Cross flame distance at which side view contours to be plotted = 0 m

Trench Fire

Trench Fire Summary

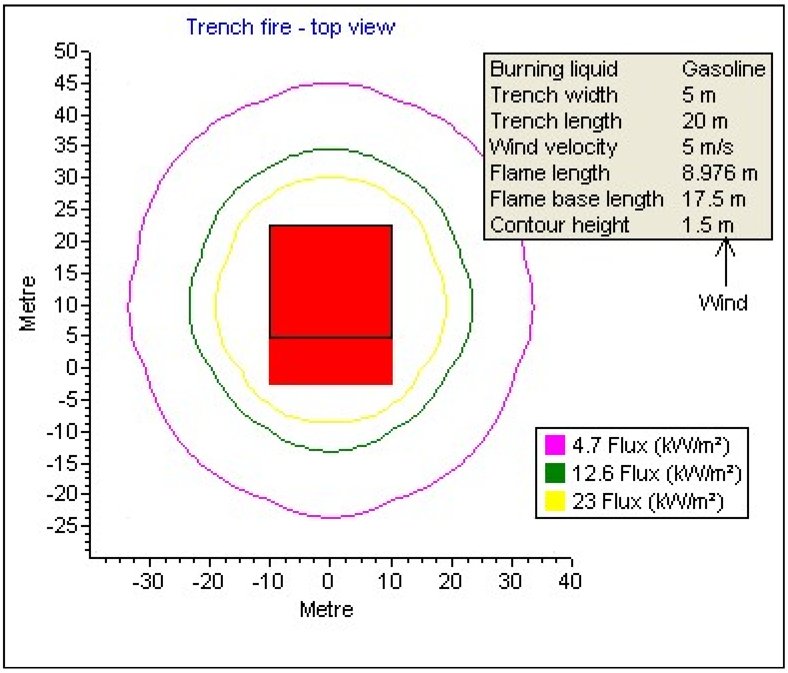
Flame length = 8.976 m
Flame angle from vertical = 55.94 deg
Flame base length = 17.5 m
Surface emissive power (top) = 130 kW/m²
Surface emissive power (bottom) = 130 kW/m²
Clear flame height = 5.027 m

Side view



Raw plot data

Top view



[Raw plot data]

E1

Scenario Summary

Scenario

Scenario = E1
Fluid = Ethanol

Trench

Width = 5 m
Length = 20 m
Angle from north = 90 deg

Weather

Ambient conditions

Temperature = 20 °C
Relative humidity = 70 %
Wind speed = 5 m/s
Direction wind is going to = 0 deg
(measured clockwise from North)

Atmospheric stability conditions

Define by = Pasquill class
Pasquill class = D Neutral

Thermal radiation

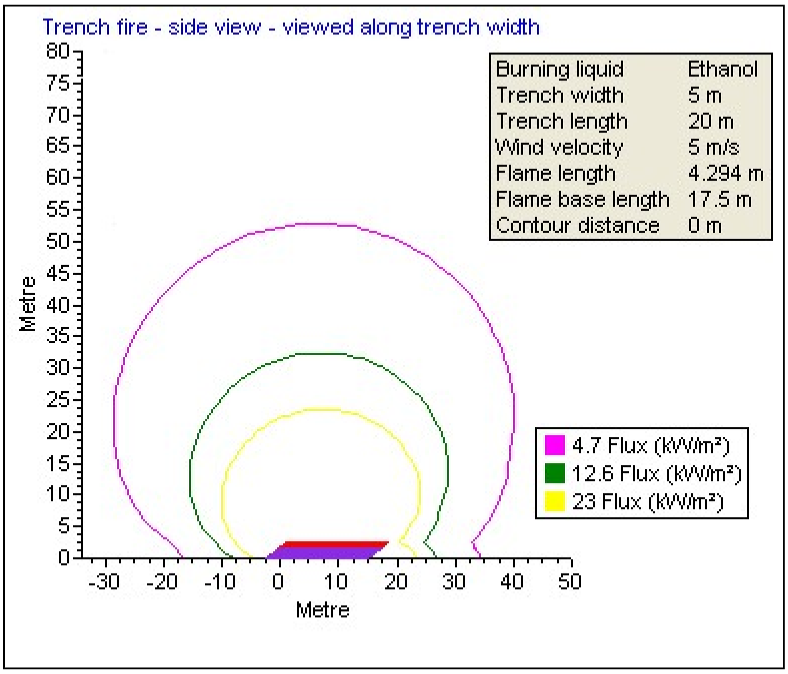
Radiation contours = 4.7, 12.6, 23 kW/m²
Height at which plan view contours to be plotted = 1.5 m
Cross flame distance at which side view contours to be plotted = 0 m

Trench Fire

Trench Fire Summary

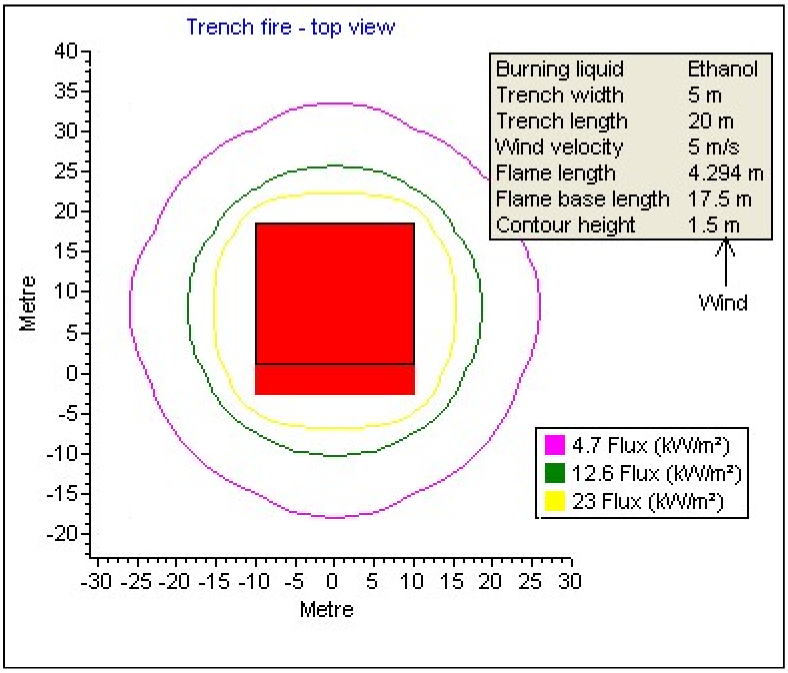
Flame length = 4.294 m
Flame angle from vertical = 55.94 deg
Flame base length = 17.5 m
Surface emissive power (top) = 130 kW/m²
Surface emissive power (bottom) = 130 kW/m²
Clear flame height = 1.579 m

Side view



Raw plot data

Top view



Raw plot data

Ethanol Leak from Process

Scenario Summary

Scenario

Scenario = Ethanol Leak from Process
Fluid = Ethanol

Process conditions

Calculate at = User input mass flow rate
Temperature = 78.12 °C
Pressure = 2.961 bara
Mass flow rate = 5 kg/s

Pressure downstream of release

Pressure = 1.013 bara
Use standard atmospheric pressure = yes

Release from

Release source = Liquid space
Liquid head = 0.1 m
Releasable liquid volume = 1000.0 m³

Hole & release geometry

Hole geometry

Failure type = Custom
Hole diameter = 0.025 m
Discharge coefficient = 0.6

Pipe

Pipe length = 0 m

Release

Release height = 5 m
Release angle from vertical = 90 deg
Release angle, clockwise from North = 0 deg

Weather

Ambient conditions

Temperature = 20 °C
Relative humidity = 70 %
Wind speed = 5 m/s
Direction wind is going to = 0 deg
(measured clockwise from North)

Atmospheric stability conditions

Define by = Pasquill class
Pasquill class = D Neutral

Thermal radiation

Radiation contours = 4.7, 12.6, 23 kW/m²
Height at which plan view contours to be plotted = 1.5 m
Cross flame distance at which side view contours to be plotted = 0 m

Dispersion

Surface roughness = 0.1 m
Contours to plot:
16500.0 ppm 33000.0 ppm 190000.0 ppm
Plot type = User
Sampling time = Instantaneous

Release summary

Mass flow rate = 5 kg/s
Flux = 10185.7 kg/m²/s
Static exit pressure = 2.264 bara
Exit temperature = 78.12 °C
Exit density = 737.2 kg/m³
Exit velocity = 13.82 m/s
Residence time = 0 s
Vapour fraction at exit = 0 mol/mol
Expanded exit velocity = 26.1 m/s
Air equivalent source diameter = 0.4508 m

Release Composition

Molecular Weight of Release = 46.07 kg/kmol

Component	Weight Fraction norm	Mole Fraction norm	Critical Temp °C	Critical Pressure bara	Molecular Weight kg/kmol	Atmos BP °C	Freeze Pt °C	Heat of Comb kJ/kg
Ethanol	1.0000	1.0000	240.8	61.32	46.07	78.29	-114.1	27760.3

Reservoir summary (at reservoir pressure)

Bubble point temperature = 108.1 °C
Dew point temperature = 108.1 °C
Vapour fraction = 0

Properties of phases (for reservoir release)

	Vapour	Liquid
Molecular weight (kg/kmol)	0	46.07
Density (kg/m³)	0	737.2
Enthalpy (kJ/kmol)	0	-34660.4
Entropy (kJ/kmol*K)	0	-96.78
Cv (kJ/kg*K)	0	2.438
Cp (kJ/kg*K)	0	3.181
Sound velocity (m/s)	0	1233.1
Viscosity (e-3 kg/m*s)	0	0.4486
Surface tension (e-3 N/m)	0	17.16

Jet Fire

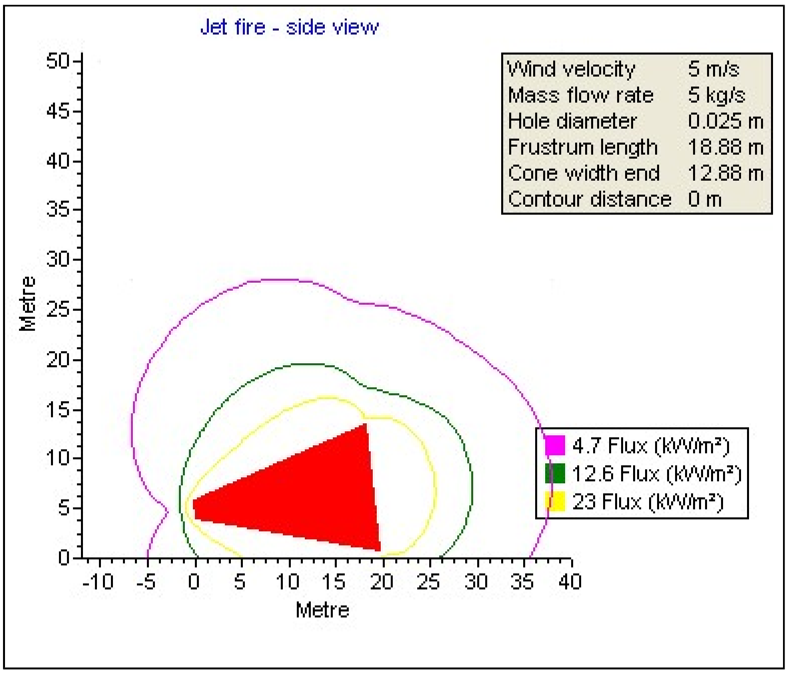
Jet Fire Summary

Flame length (of frustum) = 18.88 m
Cone width of flame base = 1.892 m
Cone width of flame end = 12.88 m
Flame lift-off = 0.04115 m

Flame angle from vertical = 83.6 deg
Flame angle, clockwise from North = 0 deg

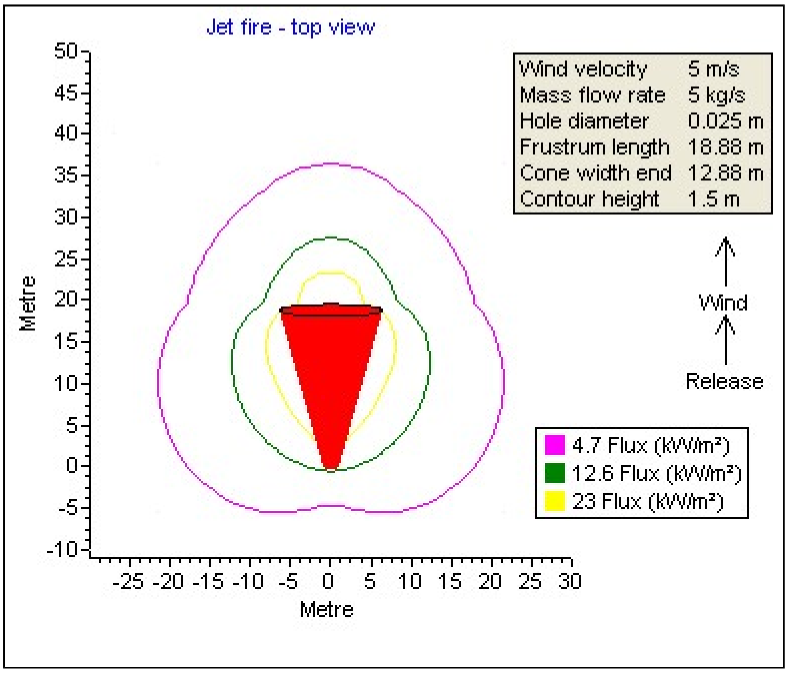
Surface emissive power = 55.7 kW/m²
Fraction of heat radiated = 0.2364
Total combustion power = 138.8 MW
Heat of combustion = 27760.3 kJ/kg

Side view



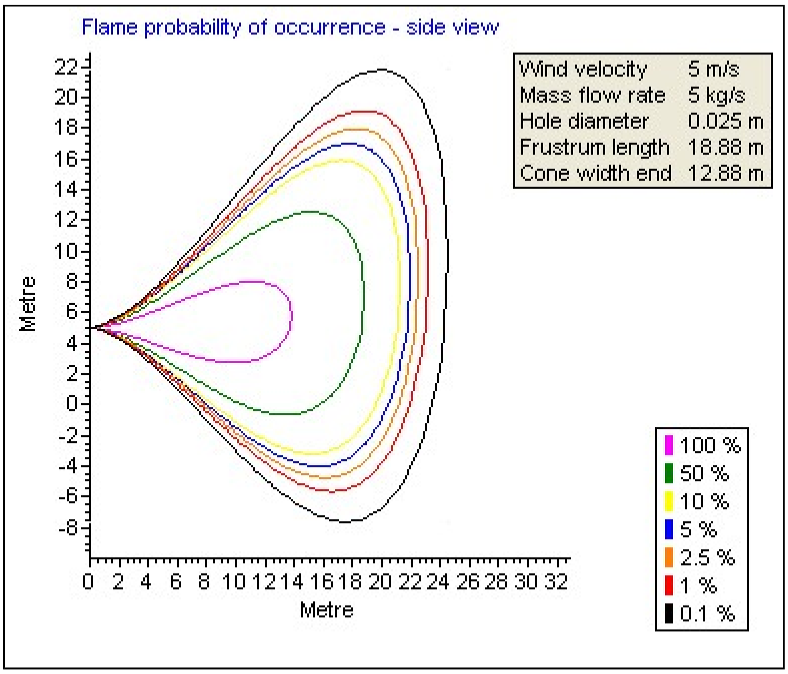
Raw plot data

Top view



Raw plot data

Impingement



Raw plot data

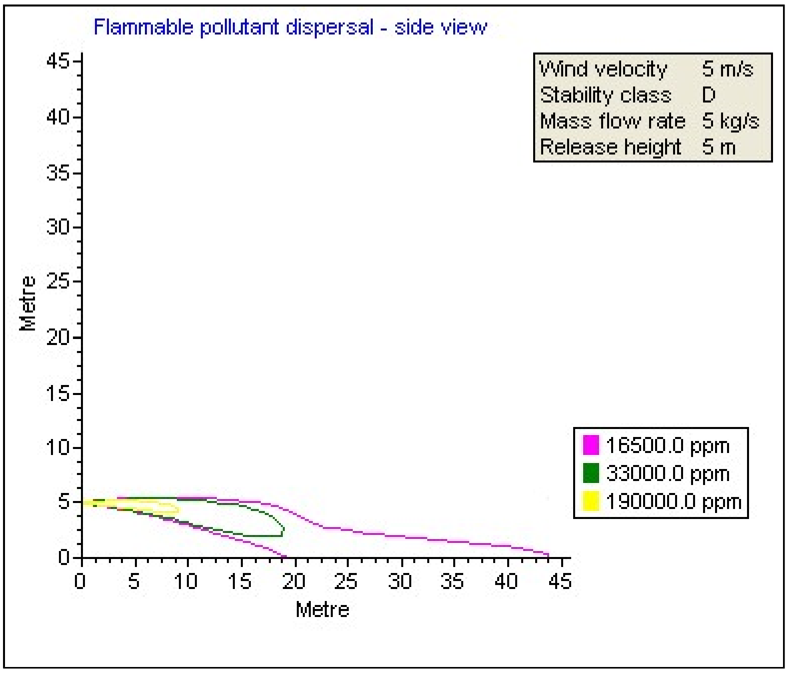
Dispersion

Dispersion Summary

Contour value (ppm)	16500.0	33000.0	190000.0
Downwind distance (m)	43.77	18.88	9.001
Height above ground (m)	0.4274	2.711	4.611

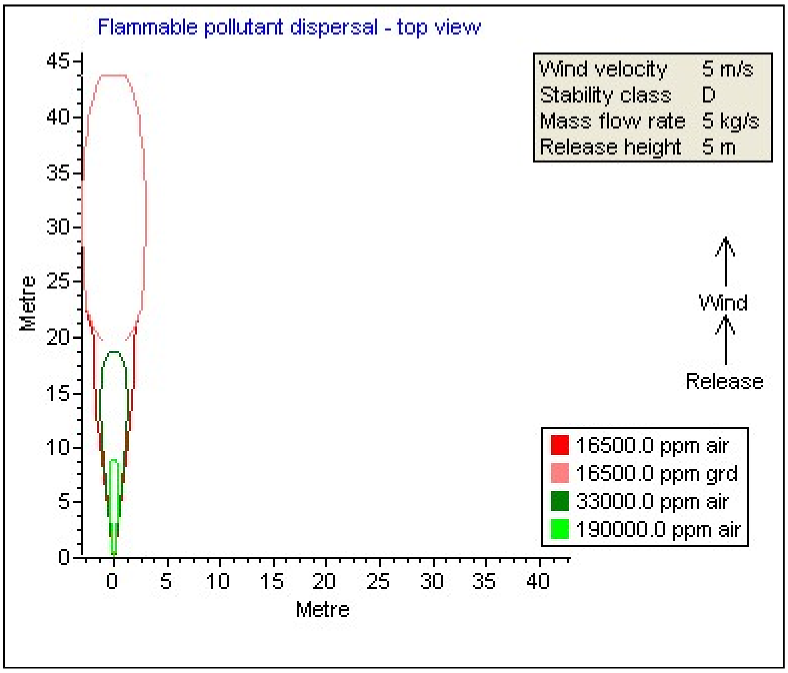
Mass in plume between specified limits = 225.4 kg
Volume of plume containing this mass = 172.5 m^3
Pollutant-only mass in this volume = 13.04 kg
Specified minimum = 1.65 vol%
Specified maximum = 100 vol%

Jet - side



Raw plot data

Jet - top



Raw plot data

APPENDIX 4. LNG STORAGE DESIGN ASSUMPTIONS

LNG Storage Facility (typical)
Assumptions Used for Consequence Modelling

Assuming 2x200m^3 LNG pressure vessels, and gas flow to the boiler of 0.38kg/s.
Assuming 3x B-double deliveries per day.

LNG Road Tanker Deliveries	Value	Unit	Value	Unit
Phase of material	liquid	-	-	-
Frequency of B-double tanker deliveries	3.0	per day	1095	p.a.
Capacity per B-double tanker	30.0	tonnes	30000	kg
Tanker temperature	126.7	K	-146.5	°C
Tanker pressure (norm. op.)	3	bar	300	kPa
Relief Valve Setting (max. op.)	6	bar	600	kPag
LNG (tanker-to-storage) fill rate	800	L/min	5.5	kg/s
Vapour return rate	800	L/min	0.07	kg/s
LNG Liquid Density	413.8	kg/m^3	-	-
LNG Vapour Density	4.9	kg/m^3	-	-

Storage (L)	Value	Unit	Value	Unit
Phase of material	liquid	-	-	-
Capacity per vessel (x 2 off)	200	m^3	82.76	tonnes
Maximum LNG fill per vessel (x 2 off)	170	m^3	70	tonnes
Temperature	126.7	K	-146.5	°C
Pressure (norm. op.)	3	bar	300	kPa
Relief Valve Setting (max. op.)	6	bar	600	kPag
LNG (storage-to-vaporiser) rate	33	te/day	0.38	kg/s
LNG Liquid Density	413.8	kg/m^3	-	-
LNG Vapour Density	4.9	kg/m^3	-	-

Vaporiser [Upstream of Pressure Regulator]	Value	Unit	Value	Unit
Phase of material	vapour	-	-	-
Temperature (sat.)	308	K	35	°C
Pressure (norm. op.)	2.75	bar	275	kPa
LNG (vaporiser-to-plant) rate	33	te/day	0.38	kg/s
LNG Vapour Density	2.37	kg/m^3	-	-

Gas Supply Line [Downstream of Pressure Regulator]	Value	Unit	Value	Unit
Phase of material	vapour	-	-	-
Temperature (sat.)	308	K	35	°C
Pressure (norm. op.)	2	bar	200	kPa
LNG (vaporiser-to-plant) rate	33	te/day	0.38	kg/s
LNG Vapour Density	2.37	kg/m^3	-	-

APPENDIX 5. REFERENCES

1. NSW Department of Infrastructure, Planning and Natural Resources (1992): *Guidelines for Hazard Analysis, Hazardous Industry Planning and Advisory Paper No. 6*, Sydney.
2. NSW Department of Infrastructure, Planning and Natural Resources (1997): *Multi-level Risk Assessment Guidelines*, Sydney.
3. NSW Government Department of Planning (1994): *Applying SEPP33, Hazardous and Offensive Development Application Guidelines*.
4. NSW Department of Infrastructure, Planning and Natural Resources (1992): *Risk Criteria for Land Use Safety Planning, Hazardous Industry Planning Advisory Paper No. 4*, Sydney.

5 NSW Department of Planning "Route Selection", Final Draft, September 1994, Sydney

6 NSW Department of Urban Affairs and Planning (1998): Guidelines for the Development of Safety management Systems, Hazardous Industry Planning and Advisory Paper No. 9, Sydney.

7 NSW Department of Urban Affairs and Planning (1993): Industry Emergency Planning Guidelines, Hazardous Industry Planning and Advisory Paper No. 1, Sydney.

8 Standards Australia (2005): *AS 3961-2005 The storage and handling of liquefied natural gas*.

9 US Coastguard Chemical Hazards Response Information System (CHRIS), www.chrismanual.com

10 The Courier-Mail: Massive ethanol tank fire sparks inquiries [29 Jan 2004]

11 NSW Department of Urban Affairs and Planning (1993): Fire Safety Study Guidelines, Hazardous Industry Planning and Advisory Paper No. 2, Sydney.

12 Environmental Resources Management Pty Ltd, Oaklands Ethanol Production Facility – Air Quality Impact Assessment, January 2007

13 NSW Department of Planning "Route Selection", Final Draft, September 1994, Sydney

14 Ronald T Noyes, Preventing Grain Dust Explosions, Current Report, http://pods.dasnr.okstate.edu/docushare/dsweb/ApplySimpleSearch/Collection-297