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PRELIMINARY HAZARD ANALYSIS

Ethanol Plant and Intensive Dairy Project

At Coleambally Irrigation Farms No.25, No.26 and No.108

FOUR ARROWS ETHANOL PTY LTD

ABN. 26116072434

Prepared By: John Marks -
Authorised By: Simon Lee -
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Moore Consulting & Engineering
Booth Associates

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Sydney	A. PO Box 7922 Baulkham Hills BC NSW 2153	T. 61 2 9894 4551	F. 61 2 9894 1318
Brisbane	A. Locked Bag 6 Fortitude Valley BC QLD 4006	T. 61 7 3854 2336	F. 61 7 3854 2337



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1	01-May-2006		John Marks	JGM	David Moore	DM	Simon Lee	SL
2	02-May-2006		John Marks	JGM	David Moore	DM	Simon Lee	SL

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Sydney **A.** PO Box 7922 Baulkham Hills BC NSW 2153 **T.** 61 2 9894 4551 **F.** 61 2 9894 1318
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1 Executive Summary

Background

Four Arrows Ethanol Pty Ltd propose a development of a facility to produce ethanol located in the Murrumbidgee Shire. As part of the preliminary design investigation Booth Associates (on Behalf of Four Arrows Group) have engaged MCE to carry out a Preliminary Hazard Analysis in accordance with the requirements of NSW Department of Planning and specifically State Environmental Planning Policy (SEPP) 33 “Hazardous and Offensive Development Application Guidelines”.

Methodology

MCE following the framework provide by the NSW Department of Planning have undertaken a Preliminary Hazard Analysis (PHA) for the design concept provided by Four Arrows Limited for an Ethanol Plant located in the Murrumbidgee Shire

This analysis comprised of several distinct stages summarised as follows:

- 1) Compilation of a profile of the dangerous goods storage on site and evaluation of the quantities and classes against those published in Table II of State Environmental Planning Policy (SEPP) 33, indicating that the development is “Potentially Hazardous” in accordance with this criteria;
- 2) As the development was determined to be “Potentially Hazardous” further analysis of the potential offsite consequences was undertaken utilising the IAEA, 1993, manual for classification and prioritisation of risks due to major accidents in process and related industries. This analysis indicated that several of the activities had the potential to produce off site risks with probability numbers in excess of 1×10^{-7} indicating further detailed assessment required. This assessment tool also identified two key findings that:
 - a) While Ethanol is the product stored in the larges quantities, it is the storage of petrol that presents a larger potential offsite risk; and
 - b) That the frequency of incidents for both ethanol and petrol were largely based on the transport activities.
- 3) Consequence modelling was undertaken to quantify the consequences of major incidents,

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determined from a hazard identification process (ref section 7). This consequence modelling determined that based on the major incidents good design (i.e. compliance with design standards and best practice and adequate separation from boundaries) significant consequences can be largely contained within the site, or at the most, cause only limited offsite effects.

Conclusion

While the facility is still in the concept design stage and therefore little detail has been provided as to the specific locations of potentially hazardous components, the analysis illustrates that, with the application of suitable design methods and utilisation of adequate separation distances, the facility should pose little additional risk to surrounding land uses (particularly noting that the current surrounding land use is farming).

Recommendations

MCE recommend that the outcomes provided in this assessment, quantifying potential risks become an integral part of the design thinking to ensure that potential consequences and offsite effects are minimised. The facility is required to meet all local and international design standards and guidance material.

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2 Introduction

The Four Arrows Limited is undertaking an Environmental Assessment (EA) process for a proposed ethanol plant and intensive dairy project to operate in the Murrumbidgee Shire, NSW, Australia. Moore Consulting and Engineering (MCE) have been engaged by Booth Associates to undertake a Preliminary Hazard Analysis (PHA) of this activity and facility. The following section describes the objectives, Study scope and Methodology employed in the PHA

2.1 *Background*

Four Arrow Ethanol Pty Ltd is one branch of the Four Arrows Group. Four Arrows has proposed the development of an ethanol and intensive dairy facility to be located in the Murrumbidgee Shire. Booth Associates has been engaged by Four Arrows Limited to undertake an investigation in the form of an Environmental Assessment (EA) for this ethanol plant and intensive dairy facility.

Booth Associates has in turn commissioned Moore Consulting and Engineering (MCE) to undertake a Preliminary Hazard Analysis (PHA) of the proposed development. This PHA is used to establish if the proposed design meets, in terms of offsite effects the required level for land use planning purposes.

The design of the ethanol plant and intensive dairy facility are in the concept design phase and to be finalised at a latter date. A PHA has been carried out based on the concept design and as such the risk assessment is expected to be updated and finalised once the final detailed designs have been released.

2.2 *Objectives*

The objective of the study is to conduct a PHA of the proposed ethanol plant and intensive dairy operations. It includes:

- Consideration of inherently safe design principles and identification of areas where the facilities design can be further enhanced.
- Preparing a PHA of the ethanol production operations, ethanol storage and distribution, petrol storage and receival in accordance with Hazardous Industry Planning Advisory Paper (HIPAP) No. 6, “Hazard Analysis Guidelines”, issued by DIPNR.
- It should be understood that a PHA is not a full risk assessment and especially at the concept

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design stage give only an indication of the potential off-site risks posed by the development

2.3 Study Scope

This PHA assesses the off-site hazards and corresponding risks associated with the ethanol plant and intensive dairy facilities. These have been deemed to include the following

- Grain receipt and Grain Storage
- Ethanol Manufacturing Process
- Ethanol Storage and Tanker Filling
- Petrol Receipt and Petrol Storage

Risks associated with the increased traffic movement do not form part of this PHA.

2.4 Method

The Four Arrows – Ethanol Plant and Intensive Dairy Project has been considered as potentially hazardous since it has exceeded the threshold levels for dangerous goods stored on site, which is set out in the *State Environmental Planning Policy (SEPP 33)*. SEPP 33 requires that once these threshold limits are exceeded that a more detailed analysis be undertaken.

This Preliminary Hazard Analysis was conducted for Booth Associates (The designated representative of Four Arrows), by Moore Consulting and Engineering (MCE), using the Department of Urban Affairs and Planning *Multi-Level Risk Assessment*, and *Guidelines for Hazard Analysis – Hazardous Industry Planning Advisory Paper No.6*.

The development of the PHA included the following steps

1. Identification of potential hazards. Evaluating the chemicals and processes undertaken on the site. Identifying each of the hazards and potential sources of loss that are associated with their storage and production.
2. Estimate the consequences of major hazardous events were determined quantitatively.
3. The effects of these consequence were examined to determine if their effects would pose an off-site risk
4. Evaluate the risks for the major hazardous incidents.

3 Site Description

This section describes the site location and layout for the Four Arrows Ethanol Plant and Intensive Dairy project at Coleambally Irrigation Farms No.25, No.26 and No. 108, Murrumbidgee Shire.

3.1 Location

The proposed ethanol plant and high intensity dairy project is to be located in the Murrumbidgee Shire. The location will be on the western side of the Kidman highway approximately seven (7) kilometres north of the township of Coleambally, and approximately 14 km south of the township of Darlington Point. This site is referred to as Coleambally irrigation farm No.25 and No.26. The site encompasses 256 hectares. The proposed development does not utilise the entire site area

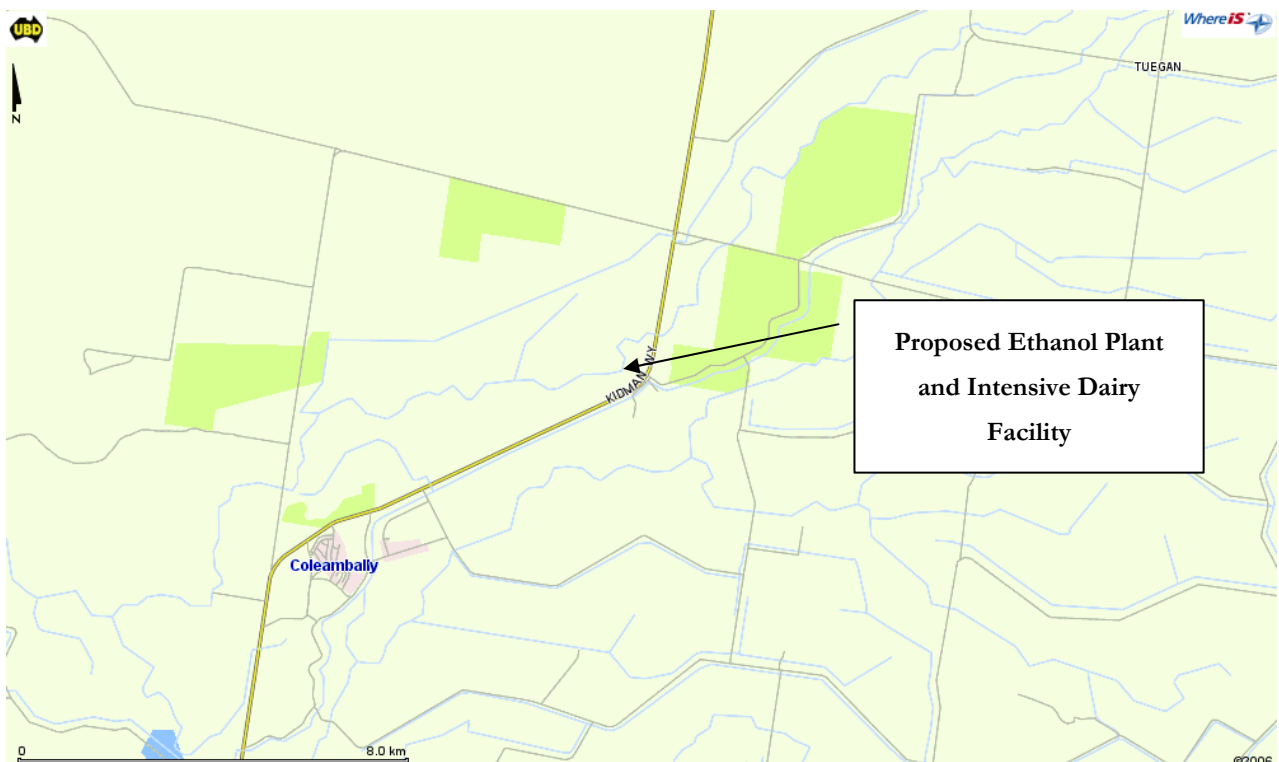


Figure 3.1 Site Location

3.2 Site Layout

The site layout is shown below in figure 3.2.

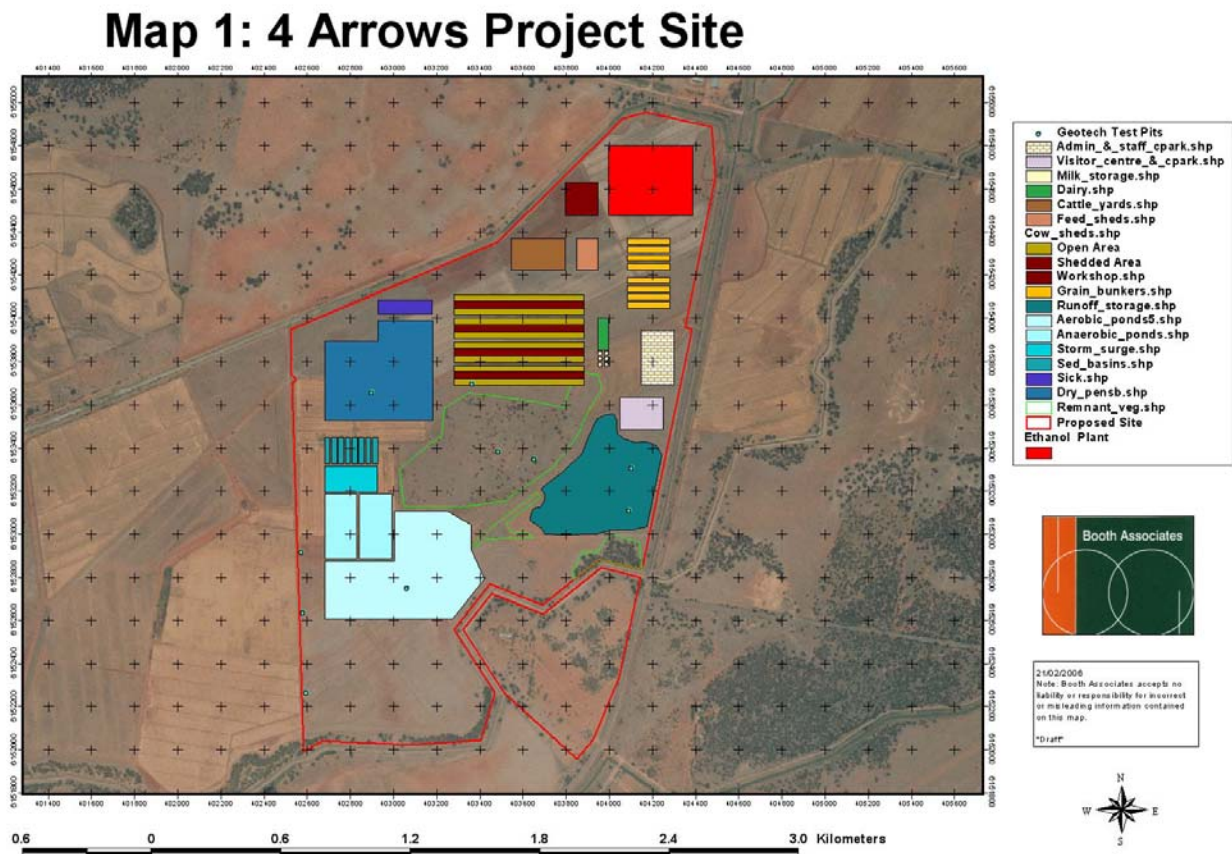


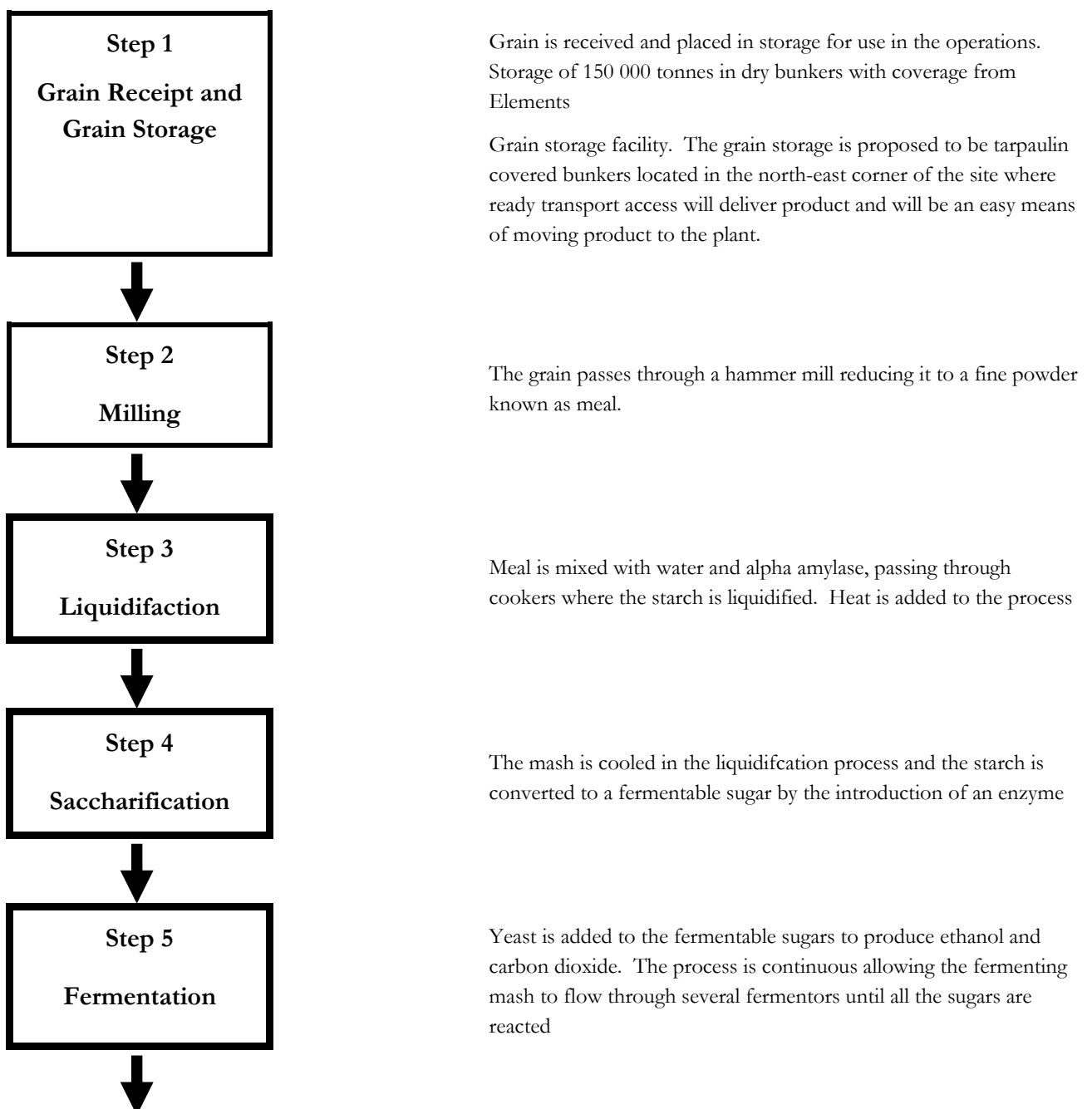
Figure 3.2 Site Layout

4 Process Description

The process description for the production of ethanol and the high intensity dairy operations are described in this section.

4.1 Ethanol Operations

The production ethanol is described in the following sequence of steps.



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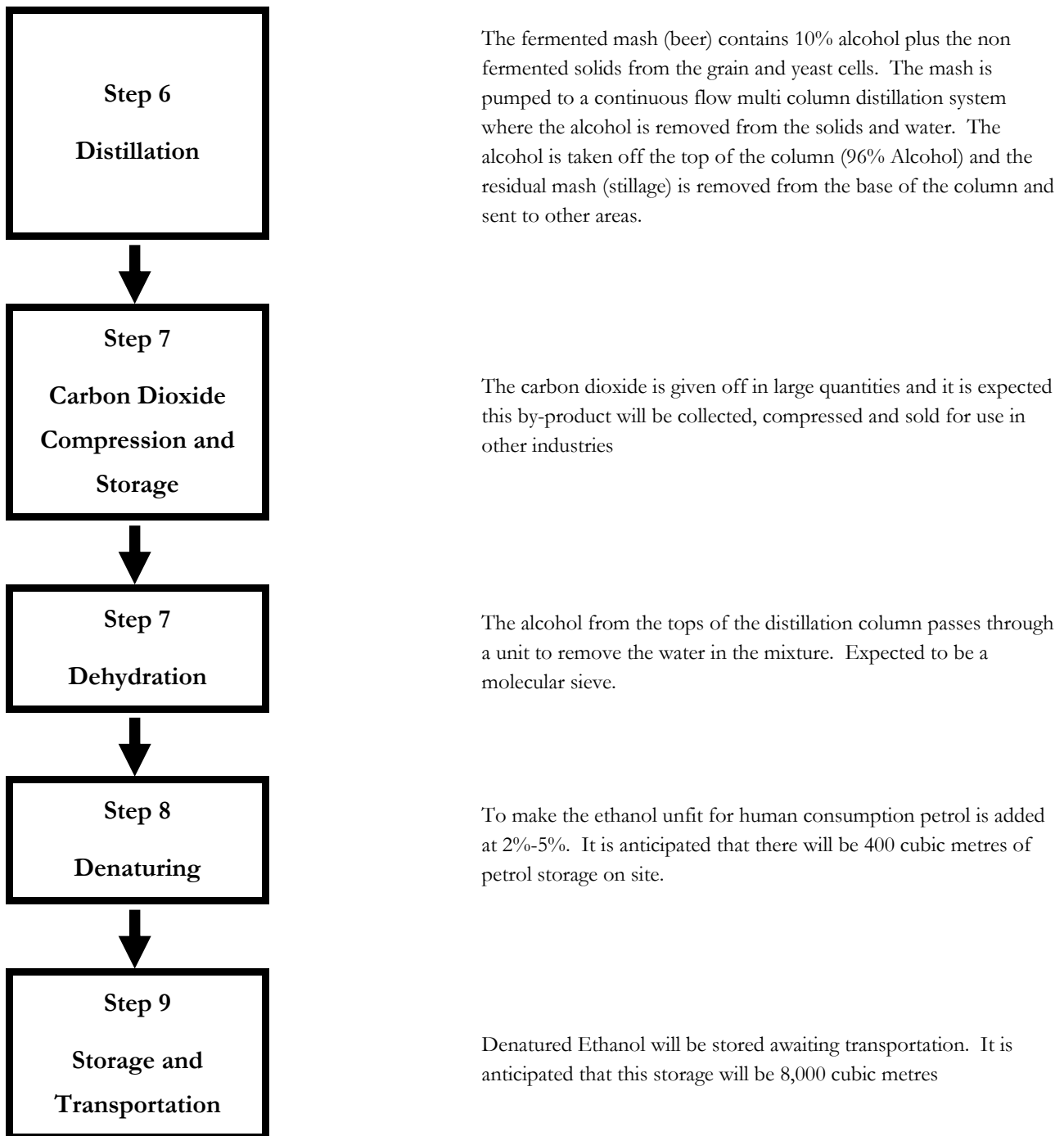


Figure 4.1 Flowchart for Ethanol Production

It is anticipated that the plant will be manned by two twelve hour shifts 7 days per week, 360 days per year employing 40-50 people

Distiller's grain is redistributed as follows:

The high moisture content product may be bulk dried down to 70% before delivery direct to the feed mill at the dairy on a regular, almost daily, basis.

The remaining wet distiller's grain is expected to be dried by centrifuge and belt press down to estimated 50% to 70% moisture subject to the financial costs associated with moving the product off-site to regional intensive animal industries.

4.2 High Intensity Dairy Operations

There are two (2) distinct components to the dairy enterprise. The first of the components is sustaining a milking herd of 6,000 cows. This milking herd will require an additional 1,200 dry cows and/or first calf heifers to ensure 6,000 cows are constantly in milk.

The second component of the dairy enterprise is a heifer raising and marketing business, which maximises the rate of genetic selection for the milking, herd and optimises marketing opportunities.

As part of the dairy operations there will be a commodity sheds and a feed mill. Situated near the north-east corner of the free-stall sheds is expected to be a commodity shed where bulk supplies of materials ready to deliver in their right proportion to the feed mill will be stored and readily accessed.

The feed mill will be immediately adjacent to the commodities shed, and of a simple nature to mix feed and have it ready for the cattle which will be fed regularly. The commodity shed is on the northern side with high roof to allow semi-trailers to tip loads into each bin. Each bin will be separated by a concrete wall and have concrete floor and large concrete apron in the front area.

4.3 *Hazardous Materials*

This section lists the anticipated inventories of hazardous material to be held at the ethanol and intensive dairy operations plant

Chemical	General Description	Quantity
Ethanol	In Process (Distillation)	267 m ³
Ethanol (Denatured)	Flammable Liquid (in storage Tank)	8000 m ³
Petrol	Flammable Liquid	400 m ³

Table 4.1 Inventory of Hazardous Materials

5 IAEA¹ Consequence and Frequency Analysis

This section applies the IAEA model for assessment of societal risk (As per HIPAP). This method is used to provide information that will help further develop the risk assessment method used in this report.

5.1 IAEA Consequence Analysis

The following section investigates the consequences using the IAEA method. There are three (3) activities investigated. These areas of concern are ethanol production (distillation), ethanol storage and petrol storage.

Application of the IAEA method is summarised in the following table

Description	Class	Storage	IAEA Table IV	Effect distance	Effect Area	Density Population	Population Correction Factor	Correction Factor for Mitigation	Est. of external Consequences (fatalities)
					A	d	f _a	f _m	C _{a,s}
Ethanol Operations	3 PG II	200 T	B1	50	0.8	5	1	1	4
Ethanol Storage	3 PG II	6000 T	B1	50	0.8	5	1	1	4
Petrol Storage	3 PG II	300 T	B1	50	0.8	5	1	1	4

Table 5.1 IAEA Consequence Analysis

Table 5.1 reveals the IAEA estimation of external consequences. These external consequence results are dominated by the population density of the surrounding land use. The estimation of the external consequences is low at 4.

¹ Manual for Classification of Risk due to Major Accidents in Process and Related Industries. (IAEA, 1993)

5.2 IAEA Frequency Analysis

The IAEA frequency analysis was calculated and the results are summarised in Table 5.2

Description	Class	Storage	Average Probability Number	Correction for Loading Unloading	Correction for flammables	Correction for organisation safety	Correction for Wind Direction	Overall	Converted to P
			$N_{i,s}^*$	n_l	n_f	n_o	n_p	$N_{i,s}$	P
Ethanol Operations	3 PG II	200 T	7	0	0	0	0	7	1×10^{-7}
Ethanol Storage	3 PG II	6000 T	8	-2	0	0	0	6	1×10^{-6}
Petrol Storage	3 PG I	300 T	7	-2	0	0	0	5	1×10^{-5}

Table 5.2 IAEA Frequency Analysis

The frequency analysis shown in table 5.2 highlights two (2) key features:-

- The likelihood of a major hazardous incident involving ethanol and petrol storage is directly related to the number of loading and unloading activities undertaken.
- The likelihood of a hazardous event occurring with petrol is increase due its high partial pressure and lower flammability limit compared to ethanol.

These findings are discussed in further detail in the consequence analysis (section 7) and provide a platform for the hazard identification undertaken in section 6

5.3 IAEA Summary

The three (3) operations discussed in this section, ethanol operations ethanol storage and petrol storage are now plotted on a graph (figure 5.1)

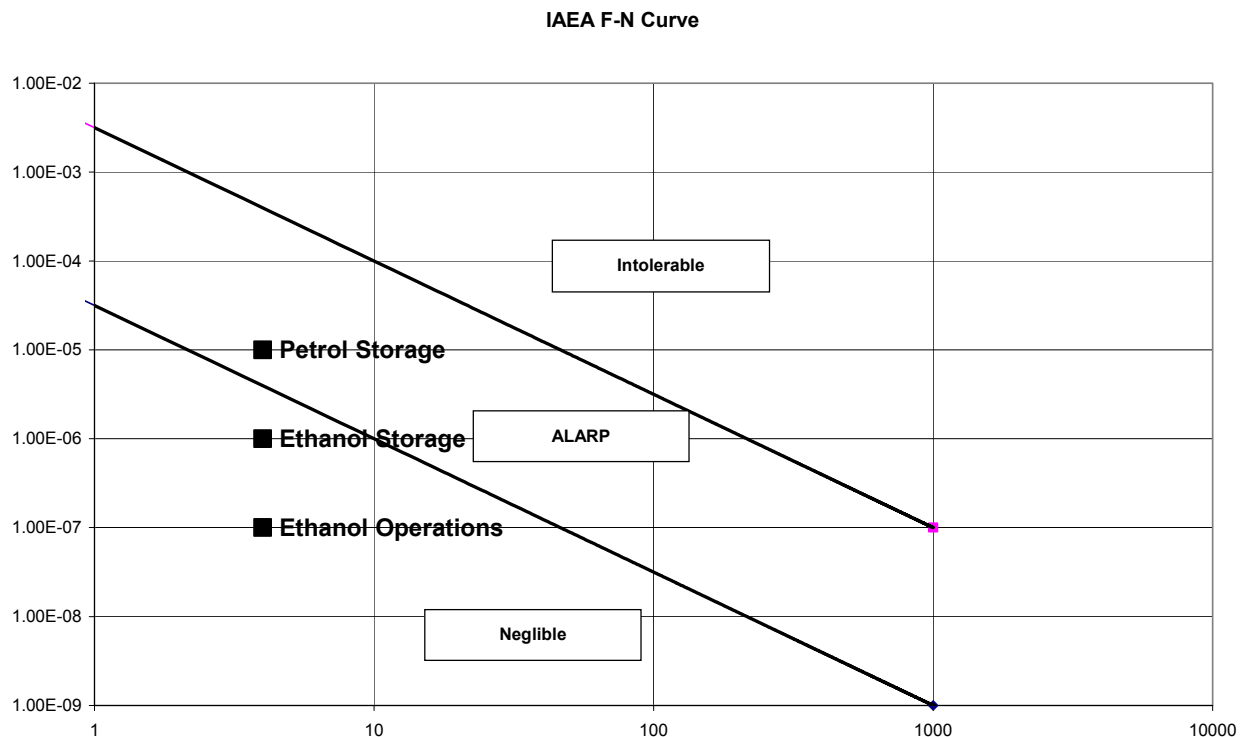


Figure 5.1 IAEA F-N Curve Individual

The analysis has revealed that although the storage quantities of petrol are less than that of ethanol the risk associated with petrol should not be underestimated. The frequency (F) was heavily dominated by the petrol storage. Care must be taken not to dominate the hazard analysis with ethanol operations and storage and neglect the petrol operations.

The combined effect of these risks is shown in figure 5.2. There is a low consequence (N) for each event placing the facility in the “As Low as Reasonably Practical” (ALARP) region of the figure.

The DUAP guidelines for Multi-Level Risk Assessments (page 17) recommend that “quantification should be carried out on any component of the risk classification and prioritisation which has an off-site consequence at a frequency of greater than 1×10^{-7} .” All three activities have frequencies at or above 1×10^{-7} and the hazard identification for the site is undertaken in section 6.

6 Hazard Identification

The types of major hazards to people, the environment and property, inherent in operations of industrial and other activities are generally derived from the energy of the “systems” in operation. The types of energy include:

- **Kinetic energy:** the momentum of moving vehicles, such as in collision resulting in damage to the vehicle and to the object that is struck.
- **Potential energy:** the energy of heavy weights that can fall, such as structures and materials being handled.
- **Chemical energy:** the heat energy obtained from combustion of materials, goods being transported, such as results in fires, explosions and fireballs.

6.1 *Potential Sources of Loss*

Potential sources of loss that arise from hazards include:

- Death or injury to people
- Damage to property
- Damage to the environment
- Loss of production and hence loss of profit from sales
- Loss of reputation

6.2 *Typical Causes*

Typical causes of hazardous incidents include:

- Fire
- Explosion
- Toxic escape
- Loss of utilities

- Electrical accident
- Structural collapse or damage
- Natural disaster
- Sabotage, vandalism, terrorism etc.

The identified hazards are summarised in Table 6.1

6.3 *Major Hazards associated with Flammable Liquids*

- These liquids have a low flash point and will be easily ignited by heat, spark or flames at ambient temperatures.
- Vapours will form explosive mixtures with air
- Vapours will travel to source of ignition and flash back
- Containers may explode when heated
- Vapours from runoff may create an explosion hazard
- May be ignited by heat, sparks or flame

Table 6.1 Hazard Identification Table

Ref. No	Operational Area	Event	Cause	Possible Consequence	Proposed Prevention and Mitigation/Control Measures
1	Grain Receival	Fine Dust and Air Mix	Displacement of fine dust build up into the atmosphere	Dust Explosion. The dust explosion requires a source of ignition. This explosion could cause the following Injury to Operating Personnel Damage to equipment Secondary fires	Plant Hygiene Training, procedures and audits. Control of ignition sources on site. Hot work controlled via hot work permits. Design to minimize dust accumulation areas
2	Grain Storage	Fine Dust and Air Mix	Displacement of fine dust build up into the atmosphere	Dust Explosion. The dust explosion requires a source of ignition. This explosion could cause the following Injury to Operating Personnel Damage to equipment Secondary fires	Plant Hygiene Training, procedures and audits. Control of ignition sources on site. Hot work controlled via hot work permits. Design to minimize dust accumulation areas
3	Grain Storage	Maintenance in Grain Storage Area	Displacement of fine dust build up into the atmosphere	Fire – Caused by introduction of a source of ignition	Plant Hygiene Training, procedures and audits. Control of ignition sources on site. Hot work controlled via hot work permits. Design to minimize dust accumulations
4	Grain Conveying	Fine Dust within equipment and Air Mix	Use of pneumatic conveyors	Dust Explosion. The dust explosion requires a source of ignition. This explosion could cause the following Injury to Operating Personnel Damage to equipment Secondary fires	Plant Hygiene Use of Explosive panels on pneumatic conveyor or baghouses Control of Static electricity

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Ref. No	Operational Area	Event	Cause	Possible Consequence	Proposed Prevention and Mitigation/Control Measures
5	Milling	Fine Dust and Air Mix	Displacement of fine dust build up into the atmosphere	Dust Explosion. The dust explosion requires a source of ignition. This explosion could cause the following Injury to Operating Personnel Damage to equipment Secondary fires	Plant Hygiene Training, procedures and audits. Control of ignition sources on site. Hot work controlled via hot work permits. Design to minimize dust accumulations
6	Distillation	Release of alcohol vapour at Flash Point for vessel or pipework	Mechanical damage Corrosion Overpressure Under pressure Excessive - Temperature	Vapour Cloud Explosion - Release of alcohol cloud could find an ignition source. In the distillation process the alcohol has been heated to a vapour	Regular maintenance and inspection Space between the distillation building and other building to be 30m Ventilation of the building to ASTM E1344 – 90 Hazardous zoning of the area around the vessel to zone 1 within 3m Fire fighting equipment will be provided Personal protection and spill equipment to be provided Appropriate materials of construction for service. Preventative maintenance program on critical piping items (e.g. safety valves). Training, procedures and audits. Control of ignition sources on site. Hot work controlled via hot work permits.

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Ref. No	Operational Area	Event	Cause	Possible Consequence	Proposed Prevention and Mitigation/Control Measures
7	Distillation	Release from Pipework or Distillation Column	Mechanical damage Corrosion Overpressure	Pool Fire – Release of ethanol finds a source of ignition The release of ethanol escapes into the environment	Installation of bunded area manufactured to meet or exceed industry and statutory requirements: AS 1692 and AS 1940 Regular maintenance and inspection Bund sized for adequate containment Fire fighting equipment will be provided Personal protection and spill equipment to be provided Appropriate materials of construction for service. Preventative maintenance program on critical piping items (e.g. safety valves). Training, procedures and audits. Control of ignition sources on site. Hot work controlled via hot work permits. Emergency response actions for fire fighting (site crew), rescue, First Aid etc
8	Molecular Sieve	Release from Pipework or Molecule Sieve	Mechanical damage Corrosion Overpressure	Pool Fire – Release of ethanol finds a source of ignition The release of ethanol escapes into the environment	Installation of bunded area manufactured to meet or exceed industry and statutory requirements: AS 1692 and AS 1940 Regular maintenance and inspection Bund sized for adequate containment Fire fighting equipment will be provided Personal protection and spill equipment to be provided Appropriate materials of construction for service. Preventative maintenance program on critical piping items (e.g. safety valves). Training, procedures and audits. Control of ignition sources on site. Hot work controlled via hot work permits. Emergency response actions for fire fighting (site crew), rescue, First Aid etc

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Ref. No	Operational Area	Event	Cause	Possible Consequence	Proposed Prevention and Mitigation/Control Measures
9	Ethanol Storage	Release of Ethanol from tank rupture or pipework failure	Mechanical damage Corrosion Overpressure Under pressure	Vapours of Ethanol form a flammable cloud eventually reaching on ignition source and causing a vapour cloud explosion	Appropriate materials of construction for service. Preventative maintenance program on critical piping items (e.g. safety valves). Training, procedures and audits. Control of ignition sources on site. Hot work controlled via hot work permits
10	Ethanol Storage	Tank Rupture	Mechanical damage Corrosion Overpressure Under pressure	Pool Fire – Release of Ethanol finds a source of ignition The release of ethanol escapes into the environment	Tanks and bunded manufactured to meet or exceed industry and statutory requirements: AS 1692 and AS 1940 Monitoring of interstitial space between tank and outer bund Regular maintenance and inspection Bund sized for adequate containment Fire fighting equipment will be provided Personal protection and spill equipment to be provided Appropriate materials of construction for service. Preventative maintenance program on critical piping items (e.g. safety valves). Training, procedures and audits. Control of ignition sources on site. Hot work controlled via hot work permits. Emergency response actions for fire fighting (site crew), rescue, First Aid etc
11	Ethanol Storage	Pipe rupture or leak	Mechanical damage Corrosion Overpressure Pipe work	Pool Fire – Release of ethanol finds a source of ignition The release of ethanol escapes into the environment	Selection of Correct Pressure Pipework and Pumping Systems Regular maintenance and inspection Fire fighting equipment to be installed Control ignition sources Siphon breakers at tank to minimise spills from pipes

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Ref. No	Operational Area	Event	Cause	Possible Consequence	Proposed Prevention and Mitigation/Control Measures
12	Ethanol Loading	Tanker Rupture	Collision with Vehicles	Pool Fire – Release of ethanol finds a source of ignition The release of ethanol escapes into the environment	Vehicle Management Policy Design to AS 1940 Regular testing and maintenance of tanker Personal protection and spill equipment to be provided
13	Ethanol Loading	Overfilling	Operational Error	Pool Fire – Release of ethanol finds a source of ignition The release of ethanol escapes into the environment	Overfill protection on tanker Fire fighting equipment to be provided Spill equipment to be provided Control ignition sources
14	Ethanol Loading	Pipe Rupture or leak	Mechanical Damage Corrosion of Pipe or Fittings Overpressure of hose pipe	Pool Fire – Release of ethanol finds a source of ignition The release of ethanol escapes into the environment	Design to AS 1940 Regular testing and maintenance of tanker Fire fighting equipment to be provided Spill equipment to be provided Control ignition sources Pressure testing of hoses
15	Petrol Storage	Release of Petrol from tank rupture or pipework failure	Mechanical damage Corrosion Overpressure Under pressure	Vapours of Petrol form a flammable cloud eventually reaching on ignition source and causing a vapour cloud explosion	Appropriate materials of construction for service. Preventative maintenance program on critical piping items (e.g. safety valves). Training, procedures and audits. Control of ignition sources on site. Hot work controlled via hot work permits

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Ref. No	Operational Area	Event	Cause	Possible Consequence	Proposed Prevention and Mitigation/Control Measures
16	Petrol Storage	Tank Rupture	Mechanical damage Corrosion Over Pressure Under Pressure	Release of petrol to bund Possible bund fire or tank fire if ignited	Tanks and banded manufactured to meet or exceed industry and statutory requirements: AS 1692 and AS 1940 Monitoring of interstitial space between tank and outer bund Regular maintenance and inspection Bund sized for adequate containment Fire fighting equipment will be provided Personal protection and spill equipment to be provided Appropriate materials of construction for service. Preventative maintenance program on critical piping items (e.g. safety valves). Training, procedures and audits. Control of ignition sources on site. Hot work controlled via hot work permits. Emergency response actions for fire fighting (site crew), rescue, First Aid etc
17	Petrol Storage	Pipe rupture or leak	Mechanical damage Corrosion Overpressure Pipework	Release of petrol to bund Possible bund fire or tank fire if ignited	Selection of Correct Pressure Pipework and Pumping Systems Regular maintenance and inspection Fire fighting equipment to be installed Control ignition sources Siphon breakers at tank to minimise spills from pipes
18	Petrol Receipt	Tanker Rupture	Collision with Vehicles	Pool Fire Loss of Petrol into the environment	Vehicle Management Policy Design to AS 1940 Regular testing and maintenance of tanker Personal protection and spill equipment to be provided

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Ref. No	Operational Area	Event	Cause	Possible Consequence	Proposed Prevention and Mitigation/Control Measures
		Pipe Rupture or leak	Mechanical Damage Corrosion of Pipe or Fittings Overpressure of hose pipe	Release of Petrol from tanker - Pool Fire may result if ignition source present Dispersal of spill without ignition	Design to AS 1940 Overfill protection on tank Regular testing and maintenance of tanker Fire fighting equipment to be provided Spill equipment to be provided Control ignition sources
19	Boiler	Gas Release	Mechanical damage to Pipe Overpressure of Pipe	Vapour Cloud Explosion – Release of Gas and ignition. Jet Fire – Release of pressurised gas find an ignition source	Selection of correct pipework Regular Maintenance and inspection Control of ignition sources
20	Commodity Shed	Storage of Material starts to decompose.	Ignition source introduced into dry storage area Internal heat build up in stock	Fire – Dry Materials being stored requiring source of ignition Fire – Internal Heat build up through decomposition of material	Rotation of Material Fire fighting equipment to be provided Control ignition sources
21	Carbon Dioxide Compression	Failure of Storage Vessel	Overpressure Mechanical Damage to fittings	Release of carbon dioxide cloud which displaces oxygen in atmosphere	Pressure relief Valves Vessel manufactured to meet or exceed industry and statutory requirements. Appropriate materials of construction for service. Preventative maintenance program on critical piping items (e.g. safety valves).

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7 Consequence Analysis

This section discusses the potential consequences of the hazards identified in section 6. There has been some grouping of the hazardous incidents in order to identify the hazards that have potential for significant off-site effects

7.1 *Grain Dust Explosions*

There were a number of grain dust explosion scenarios identified in the hazard identification section 0. These included dust explosions identified for:-

- Grain receival (Ref No.1)
- Grain Storage (Ref No. 2)
- Grain Conveying (Ref No.4)
- Milling (Ref No. 5)

The effects of a grain dust explosion are normally confined to the building or area in which the event occurs. These explosions can cause damage to equipment within the confined space in which the explosion occurs. Personnel within the building could experience an overpressure blast capable of causing injury or death.

The HSE, Dust explosions in the food industry -information sheet², list a food grade dust explosion as weak. The material handled in this facility is similar to those listed in this information sheet. In comparison to the potential of a vapour cloud explosion from a flammable liquid the effects of a dust explosion are unlikely to have significant effects off-site.

7.2 *Grain Storage Fires*

There were a number of grain storage fires scenarios identified in the hazard identification section 0. These included grain fires identified for:-

- Grain Storage (Ref 3)
- Commodities Shed (Ref 20)

² <http://www.hse.gov.uk/pubns/fis02.pdf>

The effect of a fire in the grain storage areas will not be as extensive as those caused by the release of a flammable liquid such as ethanol or petrol. It is unlikely that the heat radiation generated by a grain fire will pose a significant off-site effect.

7.3 Vapour Cloud Explosion - Distillation Building

The release of ethanol vapour from the distillation column could result in the formation of a vapour cloud. This ethanol vapour is released within the confinements of the ethanol distillation building and if the vapour cloud finds a source of ignition a vapour cloud explosion (VCE) could result.

The resulting vapour cloud explosion results in a blast wave being produced. This has been modelled by a space of approximately 300 m³ was filled with ethanol and ignited. 300 m³ has been used

These results are shown in the table 7.1

Overpressure (KPa)	Maximum isopleth distance (m)
21.0	50.1
35.0	29.7
70.0	17.9

Table 7.1 Distillation Building VCE Effects

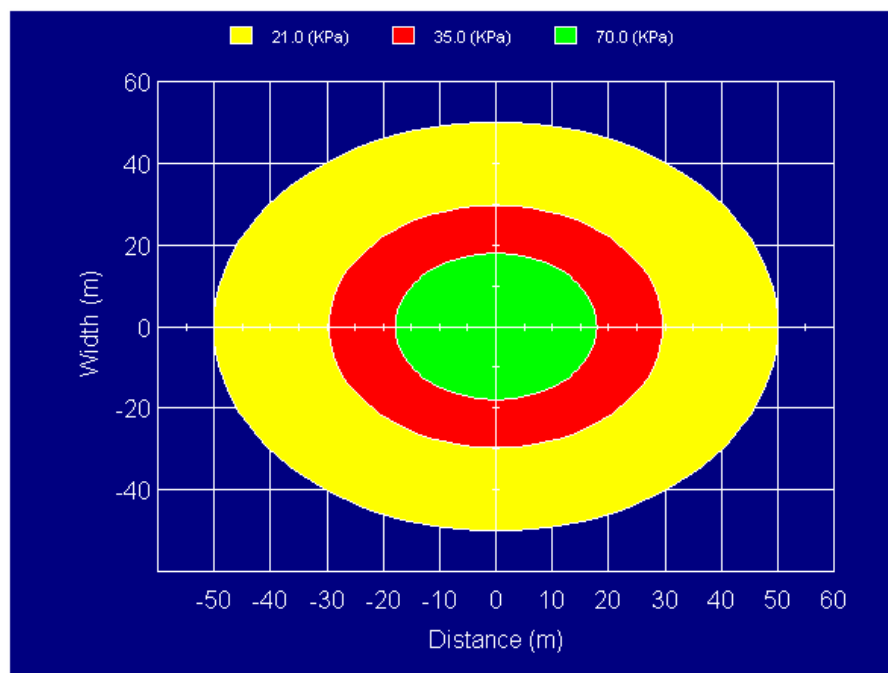


Figure 7.1 Distillation Building VCE Effects

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As can be seen from table 7.1 and figure 7.1 there are significant overpressure levels within the distillation building resulting in severe damage to the building and structure. Personnel within the building may be affected. The offsite effects are to be very low and can be managed by the use of appropriate separation distances and appropriate engineering standards and best manufacturing practices.

7.4 Vapour Cloud Explosion – Ethanol

A vapour cloud explosion was a possible consequence of an ethanol release in the storage area. The cloud was assumed to contain 200 m³ of gas but the level of congestion was decreased to low. The volume of gas modelled was chosen to be area that could fill with gas before dispersion. It is considered that a cloud this large would be unlikely for ethanol.

Overpressure (kPa)	Maximum isopleth distance (m)
21.0	43.8
35.0	25.9
70.0	15.7

Table 7.2 Ethanol Storage VCE Effects

The effects of these overpressure levels are shown in table 7.2. These affects are comparable in magnitude to those for a VCE in the distillation building (section 0). In section 0 and 9.4 we will examine the likelihood of a VCE for ethanol production and ethanol storage.

7.5 Pool Fire – Ethanol

An ethanol pool fire has been identified as the possible consequence for a hazardous incident for the following scenarios

- Release of Liquid from the distillation Process (Ref No.7)
- Molecular Sieve (Ref No. 8)
- Ethanol Storage (Ref No.10, Ref No. 11)
- Ethanol Loading (Ref No.12, Ref No.13, Ref No.14)

The consequences have been modelled using TRACE 9.0 for three (3) scenarios. These scenarios are discussed below. The modelling has used pure ethanol in all cases

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7.5.1 Small Pool Fire

A small pool fire is the most likely consequence of a release of ethanol from the distillation or molecular sieving operational steps. Table 7.3 displays the consequences for a small release of ethanol (1000 litres) resulting in a pool for with a diameter of 3 m.

Thermal radiation (kW/m ²)	Maximum isopleth distance (m)
1.2	19.4
4.7	11.2
12.6	7.6

Table 7.3 Heat Radiation Small Release Alcohol

7.5.2 Ethanol Bund Fire

A large release of ethanol from a tank rupture could result in the entire bunded area being filled with ethanol. This ethanol once ignited would result in a pool fire with the dimensions of 70.5 metres by 70.5 metres (this is considered worst case – full bund fire). The heat radiation for large release of ethanol into the bunded area was modelled and is shown in the table below. The fire is based on pure ethanol disregarding the petrol component.

Thermal radiation (kW/m ²)	Maximum isopleth distance (m)
1.2	247.7
4.7	98.1
12.6	43.3

Table 7.4 Heat Radiation Full Bund Fire Ethanol Storage

As the table reveals there is a significant distance of effect. This is further represented in figure 7.2. Figure 7.2 is the graphical representation of the heat radiation from a bund fire in the ethanol storage area. The centre of the fire has been placed near the edge of the ethanol plant. Further design details are required to place these contours correctly.

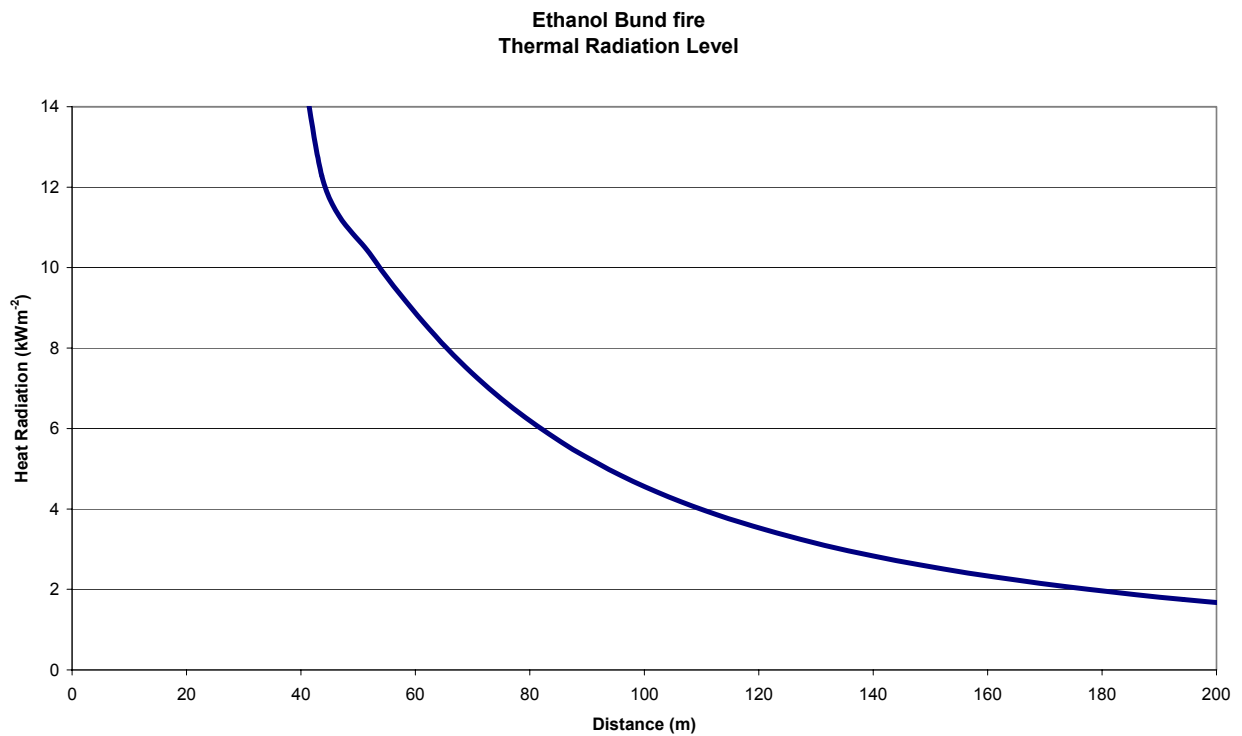


Figure 7.2 Bund Fire Ethanol Storage

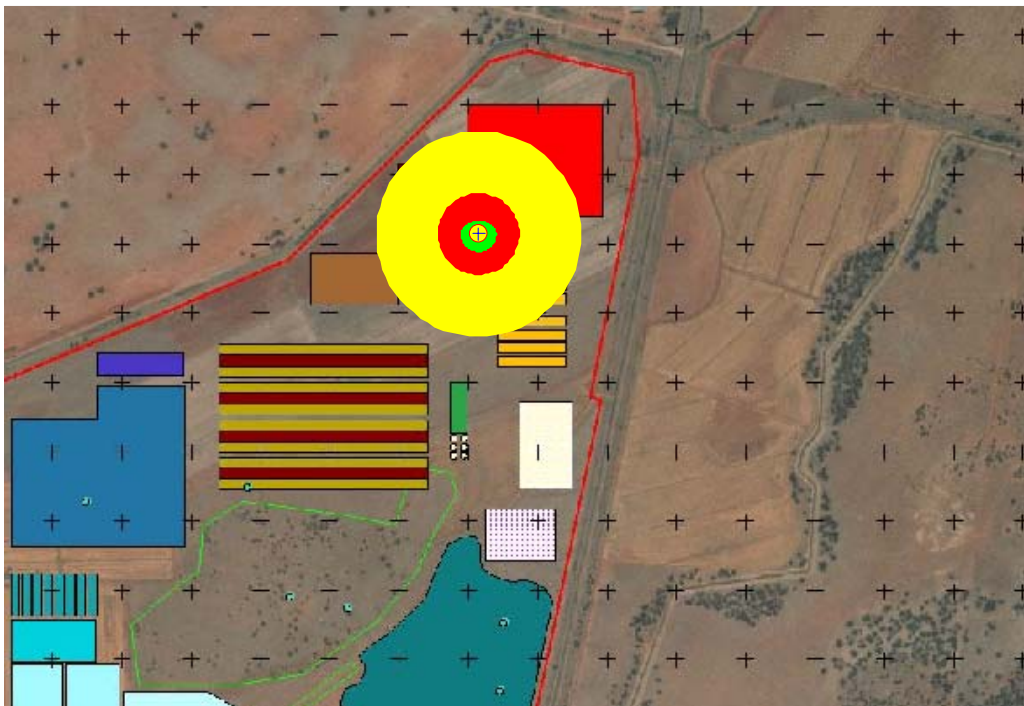


Figure 7.3 Heat Radiation Contours for Ethanol Bund Fire

Figure 7.3 represents the heat radiation levels placed on the site layout. The yellow contour representing 1.2 kW m^{-2} , the red contour representing 4.7 kW m^{-2} and the green (inner) contour representing 12 kW m^{-2} . It is of note that through correct location of the bund in relation to site

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boundary limited off-site impacts can be achieved.

7.6 *Tanker Rupture - Ethanol*

A full rupture of tanker could result in the release of 27,500 litres of fuel. This fuel will tend to spread over a larger area as it may not be bunded. This release of 27,500 litres could form a pool on average 0.03 metres deep. The resulting pool is 34.2m in diameter. The heat radiation for tanker rupture into the open was modelled and is shown in the table below:-

Thermal radiation (kW/m ²)	Maximum isopleth distance (m)
1.2	66.4
4.7	34.6
12.6	20.1

Table 7.5 Heat Radiation effects of Ethanol Tanker Rupture

These distances are not as significant as a full bund fire. It is of note that through correct location of road ways and drainage the can be limited off-site impacts achieved.

7.7 *Vapour Cloud Explosion – Petrol*

A vapour cloud explosion was a possible consequence of an ethanol release in the storage area. The cloud is modelled containing 200 m³ of gas and the level of congestion was decreased to low.

Overpressure (kPa)	Maximum isopleth distance (m)
21.0	44.3
35.0	26.3
70.0	15.9

Table 7.6 Petrol release VCE Effects

The effects of a VCE of Petrol are similar to those of a release of heated ethanol. The distance of effect can be managed through the use of separation distances from the site boundary.

7.8 *Pool Fire – Petrol*

A petrol pool fire has been identified as the possible consequence for a hazardous incident for the following scenarios

- Petrol Storage Rupture or leak (Ref No. 16 and ref No. 17)
- Delivery Tanker Rupture (Ref No. 18)
- Deliver Tanker Pipe Failure (Ref No.19)

The consequences have been modelled for two (2) scenarios. These scenarios are discussed below. The modelling was based on a multi-component mixture selected to represent petrol

7.8.1 *Bund Fire – Petrol*

A large release of petrol from a tank rupture could result in the entire bunded area being filled with petrol. This petrol once ignited would result in a pool fire with the dimensions of 25.7 metres by 25.7 metres (this scenario is considered worst case – full bund fire). The heat radiation for large release of petrol into the bunded area was modelled and is shown in the table below.

Thermal radiation (kW/m ²)	Maximum isopleth distance (m)
1.2	97.3
4.7	39.0
12.6	17.8

Table 7.7 heat Radiation Effect for a Petrol Bund Fire

These distances are shown graphically below as figure 7.4

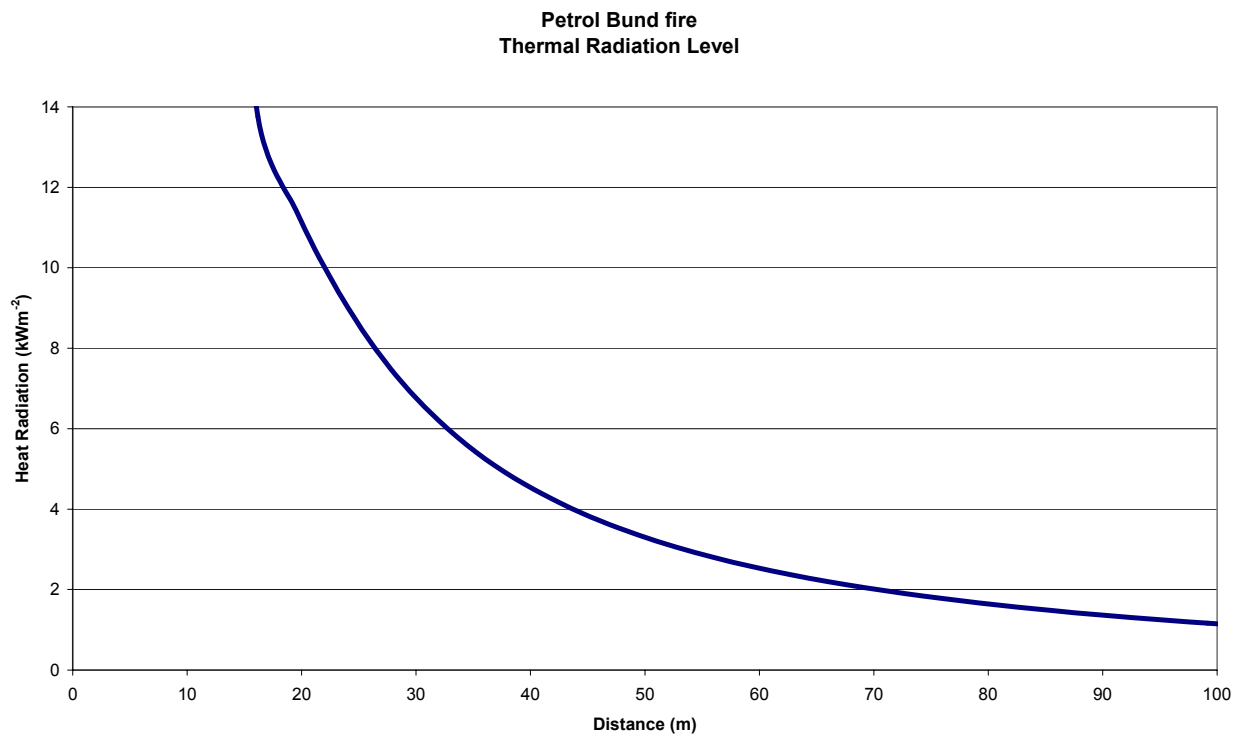


Figure 7.4 Heat Radiation Levels for a Petrol Bund Fire



Figure 7.5 Heat Radiation Contours for a Petrol Bund Fire

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The consequences of a full bund fire can be managed through the use of separation. The bunded for the petrol storage should be placed such that the consequences of effect do not have any off-site impacts.

7.8.2 Tanker Rupture - Petrol

A full rupture of a petrol tanker could result in the release of 30,000 litres of fuel. This fuel will tend to spread over a larger area as it may not be bunded. It was assumed that the 30,000 litres will form a pool on average 0.03 metres deep. The resulting pool is 35.7 m in diameter. The heat radiation for tanker rupture into the open was modelled and are shown in the table below

Thermal radiation (kW/m ²)	Maximum isopleth distance (m)
1.2	97.8
4.7	49.2
12.6	35.2

Table 7.8 heat Radiation Effects Tanker Rupture Petrol

The pool fire from a petrol tanker has a larger distance of impact than an ethanol tanker, however the time to combust all the petrol is 4.1 minutes. This is significantly less than that of an alcohol tanker release and highlights the differing energy release during the fire.

7.9 Carbon Dioxide Release

The release of liquefied carbon dioxide will produce a cloud of carbon dioxide moving close to the ground. The carbon dioxide will displace the oxygen in the atmosphere. It was assumed that exposure to a level of 10% by volume of carbon dioxide (CO₂) would cause death within a few minutes by suffocation³.

A release of pressurised carbon dioxide through a 25mm hole was modelled. It would take approximately 26 minutes to empty 10000 kg of compressed carbon dioxide. The modelling used the following atmospheric conditions, a wind speed of 5ms⁻¹ and atmospherically stability of D. This release was modelled and the results are shown in figure 7.6.

³ www.uigi.com/MSDS_liquid_CO2.html

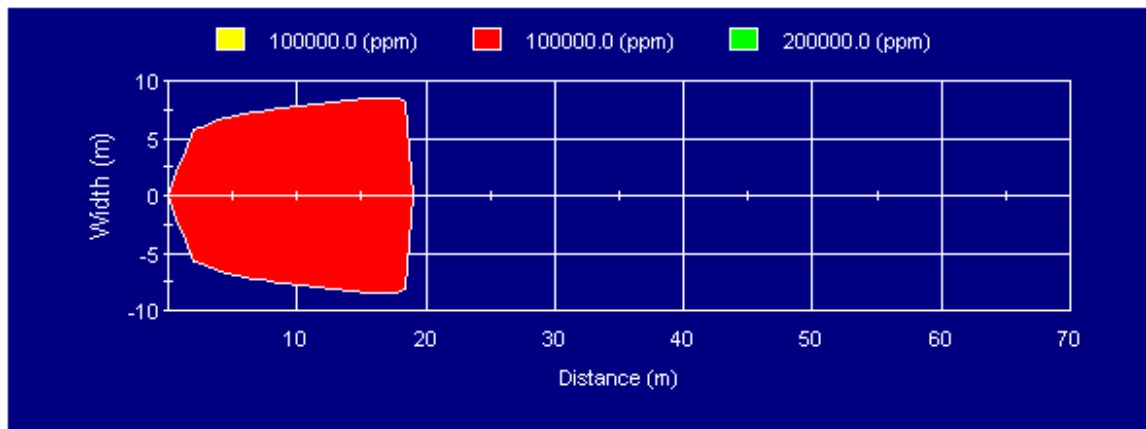


Figure 7.6 Cloud Dispersion from CO₂

As figure 7.6 reveals the distance of plume a concentrations of 10% carbon dioxide extends a very short distance from the leak source (less than 20m). It is therefore considered unlikely that a significant off-site impact will occur, if the storage of carbon dioxide is separated from the site boundary.

8 Estimation of the Likelihood of Hazardous Events

The DUAP, Multi-Level Risk Assessment Guidelines, page 17 states

“Where the risk appears to be low, quantification need only be continued to the extent needed to demonstrate that no combination of events is possible that would lead to the relevant risk criteria being exceeded. For example, the modelling of the main events show that all the consequences are confined within the site or that the events with off-site consequences are sufficiently unlikely to pose a significant risk.”

In section 7 modelling of the consequences were undertaken for potentially hazardous incidents. The use of separation distances in the final design of the facilities can result in there being negligible effect on neighbouring land areas and the consequences can be contained within the site.

The use of separation distance to mitigate the consequence effects means there is no detailed frequency analysis conducted in this report.

9 Discussion on Hazardous Events

This section provides further discussion on the hazardous events discussed in section 7

9.1 *Grain Dust Explosion*

As discussed in section 7.1 the effects of a grain dust explosion as a single event will be limited to on-site and as such no frequency analysis has been conducted. A grain dust explosion may contribute to a secondary event such as a release of flammable liquids. These secondary hazardous events may be significant enough to have off site impacts and are discussed further in this section.

9.2 *Grain Silo Fires*

In section 7.2 we discussed the consequence of a grain silo being unlikely to impact at a level of significance off-site. With this low level of off-site impact no frequency analysis has been conducted.

9.3 *VCE Distillation Building*

The operation of a distillation column will increase the temperature of the ethanol to its boiling point. This increase in the temperature increases the vapour that will flash off if a liquid was to occur. The leakage of a flammable liquid can produce a cloud of flammable gas capable of being ignited and resulting in a vapour cloud explosion (VCE). In Figure 8.1 these dispersion distance of an ethanol cloud produced by the release of boiling ethanol has been examined. The lower flammability level (LFL) for ethanol is 3.3% by volume. To allow for pockets of ethanol above the dispersion model half the LFL has been used. The modelling was undertaken using TRACE 9.0.

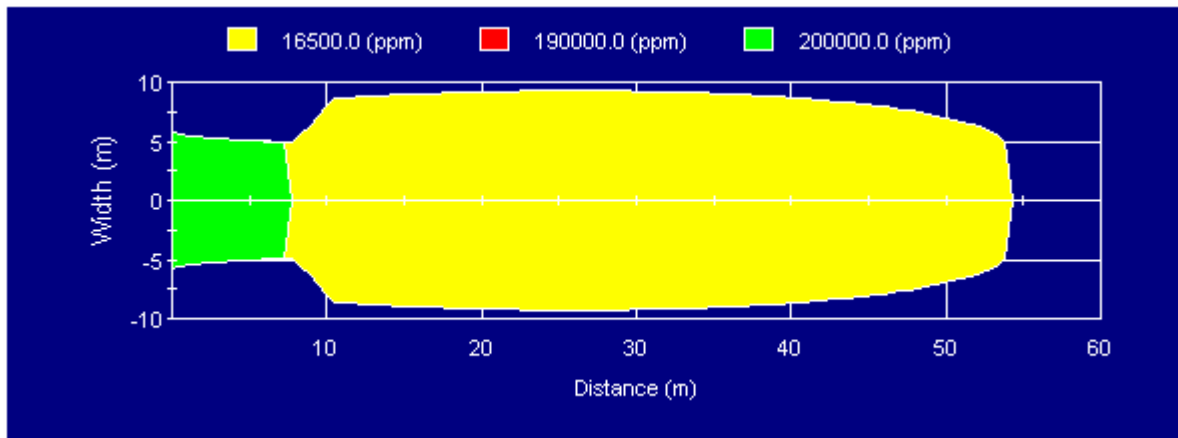


Figure 9.1 Boiling Ethanol Dispersion Cloud

As the figure 8.1 reveals if 1500 kg of boiling ethanol was released over a two (2) minute period, with a wind of 1.5 ms^{-1} (Stability D), a potentially explosive cloud approximately 50m long would form. This distance of the LFL from the release and the congestion within the distillation building would make a VCE possible for a release of ethanol at its boiling point. In section 0 the radius of a 21 kPa pressure wave was established at 50m. In order to minimise the impacts of a VCE caused by the release of ethanol from the distillation process should used. The distillation process and building should:

- Separated by 30.4m from other structures as per ASTM E 1344 – 90 (2006). The use of distances over 30.4 m will further decrease the risk
- Ventilation of the building will be adequate as per ASTM E 1344 – 90 (2006).
- All electrical installation will be zone 1 within 3m of the column and all ignition sources kept away and designed to AS 1381.
- The distillation building is a minimum of 100m from the site boundary.
- Detection of a release is integrated into the design of operations of the ethanol distillation process.

9.4 VCE – Ethanol

The leakage of a flammable liquid can produce a cloud of flammable gas capable of being ignited and resulting in a vapour cloud explosion (VCE). Ethanol has a low vapour pressure and production of a large cloud is unlikely. These key features of ethanol are shown in figure 8.2. Cooled ethanol will have a limited distance to its LFL (Lower Flammability Limit). This small distance till the concentration falls below LFL would make a VCE very unlikely for the release of cooled ethanol, assuming the correct design of the plant facilities and all electrical equipment to avoid ignition sources.

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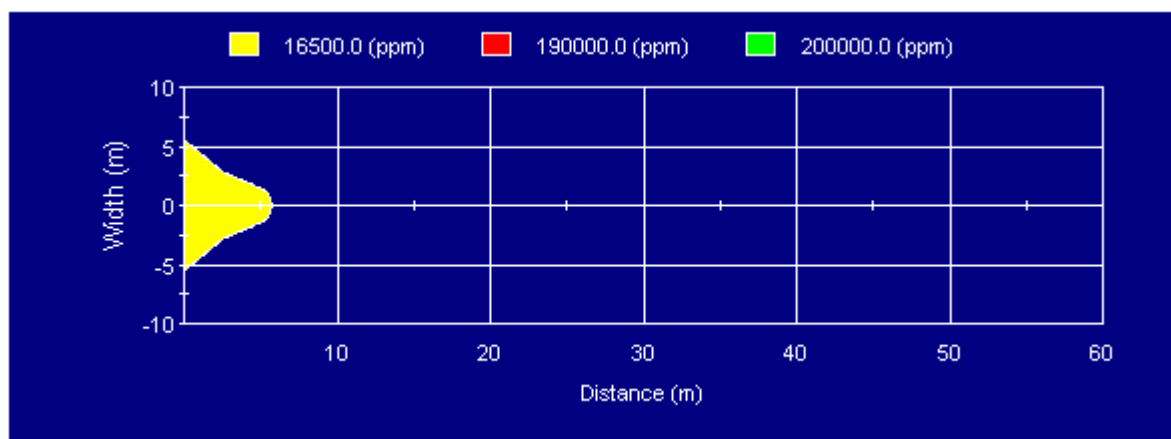


Figure 9.2 Cooled Ethanol Dispersion Cloud

For the purposes of this study it is very unlikely that a VCE with cooled ethanol will occur.

9.5 Pool Fire – Ethanol

In section 7.5 three (3) releases of ethanol were modelled to establish their consequences. These scenarios were a small pool fire in the production facilities, a full bund fire and a rupture of an ethanol tanker.

A small pool fire has limited consequences with a distance of 11m till a 4.7 kWm⁻² level is reached. The small distance of consequence is unlikely to affect any neighbouring properties. There is a possibility that this pool fire could initiate a secondary and greater event. The establishment of good manufacturing practice and use of appropriate Australian Standards in construction will help to minimise the frequency of this event.

The full bund fire and a rupture of an ethanol tanker have consequence distances which may have off-site effects. The distances should be integrated into the layout of the facilities so as to have a negligible impact both on surrounding land use and on other internal facilities. This use of separation distances has been assumed to be undertaken and, as such, no detailed frequency rate established for these events. It is imperative that a traffic management plan be implemented on the site to minimise the frequency of any incidents occurring for a flammable liquid tanker as the number of traffic movements on this site is significant.

9.6 VCE - Petrol

The vapour cloud produced a release of petrol can extend for a distance until it finds a source of ignition. A 200m³ was modelled in section 7.7. The distances to a 21 kPa pressure wave being

experienced at 44m. As consistent with other incidents described in the section the consequences on neighbouring land can be negligible through the use of separation distances and the surrounding land being zoned rural. As such no specific frequency of this event has been calculated.

9.7 *Pool Fire - Petrol*

In section 7.8 two (2) releases of petrol were modelled to establish there consequences. These scenarios were a full bund fire and a rupture of a petrol tanker.

The full bund fire for petrol and a rupture of a petrol tanker have consequence distances which may impact on neighbouring land. The distances should be integrated into the layout of the facilities so as to minimise impact both on surrounding land use and internal facilities

9.8 *Carbon Dioxide Release*

The consequences of a carbon dioxide release were examined in section 7.9. The distance of consequence is less than 20m. This use of separation distances has been assumed to be undertaken and as such no detailed frequency rate established for this events

10 Conclusions

The off site societal risks of the proposed facilities will be negligible, with a level 1 qualitative assessment meeting DIPNR guidelines. This negligible effect is based on the use of separation distances in the plant layout confining all the consequences within the site (DUAP, Multi-Level Risk Assessment, Page 15), the surrounding land use remaining rural with a low population density, the implementation of a traffic management policy, and design and operation of the facility to the appropriate Australian Standards.

11 Major Findings

A PHA was conducted for the Ethanol Plant and Intensive Dairy Facilities proposed by Four Arrows Ethanol Pty Ltd, at Coleambally Irrigation Farms No.25, No.26 and No.108. The major findings are presented below are based on the findings of the study and information made available from the Four Arrow Rural Group (as presented by Booth Associates)

- i. The major consequences in the ethanol production facilities and the ethanol storage are:
 - Vapour Cloud Explosion (VCE) in the distillation building
 - Pool Fire in Ethanol Storage
 - Pool Fire in Petrol Storage
- ii. The distillation facilities should use best industry practice to minimise the opportunity of a release of flammable liquid.
- iii. The heat radiation distances established in this report be utilised in the placement of equipment on the site. Through the use of separation distances the effects of an incident, both on site and on neighbouring land, can be minimised.
- iv. There a large number of trucking and traffic movements proposed in this development. A traffic management policy and application is critical in reducing the likelihood of the incident involving a flammable liquid tanker and therefore reducing the likelihood of a release from a flammable liquid tanker.

Appendix A Consequence Effects

A1 Effects of Heat Radiation

Heat Radiation Intensity (kW/m ²)	Heat Effects
1.21	Equivalent to heat from the sun at noon
1.6	Minimum level at which pain can be felt. This is the usual maximum for residential areas.
4.7	This is the maximum value for residential areas if the probability is low.
5-8	Will cause pain in 15-20 seconds and at least 2 nd degree burns after 30 seconds. 5 kW/m ² is the maximum level for brief exposure on an operator if protected by water sprays.
12.5	Hot enough to heat wood to a temperature where pilot ignition (e.g. spark) will start fire. This is also the maximum for areas with public access (e.g. roads) – if the probability is low ⁴
25	This intensity is sufficient to spontaneously ignite wood and thin uninsulated steel sections can reach a temperature at which thermal stresses cause failure.
75 >	The chance of fatality at a distance of less than 5m from the fire is 100% within 5 seconds.

Table A1 Effects of Heat Radiation

⁴ ICI Engineering. *Hazard Analysis Course Notes*. ICI Australia Engineering Pty Ltd (1988)

A2 Effects of Explosive Overpressure⁵

Overpressure	Effect
3.5 kPa	90% breakage of Glass
7 kPa	Damage to internal partitions and Joinery but can be repaired. Probability of injury is 10%. No fatality
14 kPa	House uninhabitable and badly cracked
21 kPa	Reinforce structures distort, storage tanks fail, 20% chance of fatality to a person in a building
35 kPa	House uninhabitable, wagons and plant items overturned, Threshold of eardrum damage. 50% chance of a fatality for a person in a building and 15% chance of fatality for a person in the open
70 kPa	Threshold lung damage. 100% chance of fatality for a person in a building or in the open.

Table A2 Effects of Overpressure

⁵ HIPAP No.4 Table 4.

Appendix B Dust Explosions (Guideline)

B1 Explosion Prevention

The same concept applies to the prevention of grain dust explosions.

Grain industry safety experts teach us that there are four factors which are necessary for a grain dust explosion to occur. In addition to needing Fuel, Heat and Oxygen, a fourth ingredient--Confinement--must exist for a grain dust explosion to occur. If any of the four sides of the "Explosion Square" is removed, then the explosion is prevented.

B1.1 Fuel

Fuel is the grain dust. Grain dust, in varying amounts, is found in every load of grain delivered from the farm. Grain dust can be controlled.

- Housekeeping is properly maintained--dust controlled to less than 1/8th of an inch (3mm)
- Dust control and collection equipment is properly operating.
- Leaking of dust into the work areas is promptly corrected.

B1.2 Heat

Heat, the second side of the explosion square, is often referred to as the ignition source. Controlling the ignition source, as with dust control, is often viewed as a key to grain dust explosion prevention. Much like grain dust, ignition sources can be found throughout a grain elevator or feed mill. Controlling ignition sources is imperative in the efforts to eliminate grain dust explosions. The following are some of the activities that can be used to control the ignition sources:

- Institute a Welding, Cutting & Burning Permit Program.
- Ensure that all bearings are lubricated and maintained regularly.
- Maintain all electrical equipment properly. Use only correctly classified equipment.
- No Smoking is a fundamental.
- Avoid storing flammable or combustible materials in the mill or elevator.

B1.3 Oxygen

Oxygen, like confinement, in the past has been viewed as universally present and therefore beyond the control of employees. Test and maintain all fire and explosion suppression systems.

B1.4 Confinement

Confinement is the final side of the "Explosion Square"; many operators have modified their facilities by installing explosion relief venting. Sometimes these vents are damaged or are worn out and need to be replaced. It is not uncommon for an employee to improperly replace/repair these devices in a way that would prevent their actuation in an explosion.

- Be aware of explosion relief devices and their design.
- Repair/replace explosion relief panels with proper materials and fasteners.

Appendix C Storage Volumes

In order to estimate the consequences of the hazardous events identified in this report assumption of the volume of flammable gases stored on site have been made. These assumptions are explained below

C1 Ethanol Storage

The production rate of the Four Arrows facility will be 300 ML per annum. The facility will have 10 days storage of denatured ethanol on site. This equated to 8,000,000 litres (8000 m³) of on-site ethanol storage. With maintenance considerations, quality assurance testing and delays it has been assumed that the largest tank will be 3,000 m³. It is likely that all the tanks for ethanol will be contained within a single bund.

The bund to contain the ethanol must have 130% capacity of the largest tank capacity in order to meet the requirements of AS 1940 and the NSW fire Brigade. Typical the bund wall would be made of earth and be 1 metre tall. This would equate to a cross sectional area of 3900m² for the bund. Assuming that the bund is a square in shape the dimensions of the bund would be 70.5metres by 70.5 metres.

C2 Petrol Storage

The production rate of the Four Arrows facility will be 300 ML per annum. In section C1 we calculated that the on-site ethanol storage would be 8,000,000 litres (8000 m³). In order to de-nature the ethanol (make unfit for human consumption) petrol will be added. If we assume this addition is 5% by volume of the ethanol and that there is a required storage volume on-site, then 400m³ of petrol storage on-site

The bund to contain the ethanol must have 130% capacity of the largest tank capacity in order to meet the requirements of AS 1940 and the NSW fire Brigade. Typical the bund wall would be made of earth and be 1 metre tall. This would equate to a cross sectional area of 520m² for the bund. Assuming that the bund is a square in shape the dimensions of the bund would be 25.7 metres by 25.7 metres.

C3 Flammable Transportation

There will be a number of traffic movements required for the operations. For this study it has been assumed that transportation will be undertaken by B-Double tankers transporting up to 55,000 litres of flammable liquid

C4 Distillation Process

The distillation process is the separation of the more volatile components of a mixture from the less volatile and non-volatile components. This is accomplished by heating the entire mixture to vaporise the more volatile components (ethanol) first.

A release of alcohol liquid from the top of the column will “flash” and potentially cause a vapour cloud explosion.

It has been assumed that

- The distillation building will be separated by 30.4m from other structures as per ASTM E 1344 – 90 (2006).
- The temperature at the top of the column is at the flash temperature of alcohol.
- The column operates under pressure.
- Ventilation of the building will be adequate as per ASTM E 1344 – 90 (2006).
- All electrical installation will be zone 1 within 3m of the column

C5 Carbon Dioxide Storage

In order to assess the consequences of a release of carbon dioxide an assumed storage of 100 tonnes of CO₂ is used for the ethanol facilities described in this report.