# ANNEXURE 3

**Preliminary Hazard Analysis**

**prepared by**

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# PRELIMINARY HAZARD ANALYSIS,
# CARBON DIOXIDE PLANT,
# SUPAGAS,
# BOMADERRY, NSW

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# Preliminary Hazard Analysis, Carbon Dioxide Plant, Bomaderry

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# EXECUTIVE SUMMARY

Supagas are proposing to expand their carbon dioxide ($CO_2$) production capability by building a new 50 TPD carbon dioxide plant at Bomaderry, NSW.

The plant is to be located on the Shoalhaven Starches site, i.e. adjacent to the Argyle Meats factory that now belongs to the Manildra Group of companies and which Shoalhaven Starches forms part. The site is located at 220 Bolong Road, Bomaderry.

The carbon dioxide feed to the plant will be from the fermentation process on the Shoalhaven Starches site. The carbon dioxide will be purified and liquefied to food grade quality for the food and beverage market.

The proposed plant will have an initial capacity carbon dioxide of up to 50 tonnes per day and then up to 100 tonnes per day when fully operational.

As part of the project requirements, a Preliminary Hazard Analysis is required. This report details the results from the analysis.

The risks associated with the proposed Supagas carbon dioxide plant at Bomaderry have been assessed and compared against the DoP risk criteria.

The results are as follows and show compliance with all risk criteria.

| Description | Risk Criteria | Risk Acceptable? |
|---|---|---|
| Fatality risk to sensitive uses, including hospitals, schools, aged care | $0.5 \times 10^{-6}$ per year | Y |
| Fatality risk to residential and hotels | $1 \times 10^{-6}$ per year | Y |
| Fatality risk to commercial areas, including offices, retail centres, warehouses | $5 \times 10^{-6}$ per year | Y |
| Fatality risk to sporting complexes and active open spaces | $10 \times 10^{-6}$ per year | Y |
| Fatality risk to be contained within the boundary of an industrial site | $50 \times 10^{-6}$ per year | Y |
| Injury risk – incident heat flux radiation at residential areas should not exceed 4.7 kW/m$^2$ at frequencies of more than 50 chances in a million per year or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year | $50 \times 10^{-6}$ per year | Y |
| Toxic exposure - Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure | $10 \times 10^{-6}$ per year | Y |

| Description | Risk Criteria | Risk Acceptable? |
|---|---|---|
| Toxic exposure - Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community | 50 x $10^{-6}$ per year | Y |
| Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/$m^2$ or explosion overpressures of 14 kPa in adjacent industrial facilities | 50 x $10^{-6}$ per year | Y |

Societal risk, area cumulative risk, propagation risk, transport risk and environmental risk are also concluded to be acceptable.

The primary reasons for the low risk levels from the site are the separation distances between the hazards the nearest place of residence and that high levels of carbon dioxide are required to cause fatality.

It is expected that the design review process followed by a HAZOP study will mitigate the generic release cases to acceptable levels. This will include designing the ammonia refrigeration system to the relevant Australian Standards. In addition to the HAZOP study, a significant hazardous event study has been conducted. The results have been included in this PHA as appropriate.

The following recommendations are made from the analysis in this PHA:

1. Ensure that the final design includes means to automatically isolate the carbon dioxide road tanker and storage vessels should a release during a transfer occur (vapour and liquid lines). Actuation should be local as well as remote;
2. Provide CCTV (closed circuit television) coverage of the plant to the Shoalhaven Starches ethanol control room, i.e. these operators control the source of the carbon dioxide;
3. Provide means to suppress an ammonia vapour plume. A plume could occur due to a release from the refrigeration system. Options include using hoses with personnel wearing self-contained breathing apparatus; and
4. Provide alternate emergency assembly areas given that a carbon dioxide plume can travel in any direction.

# GLOSSARY

| | |
|---|---|
| AEGL | Acute Exposure Guideline Levels |
| AS | Australian Standard |
| CATOX | Catalytic Oxidation |
| CCPS | Centre for Chemical Process Safety |
| CCTV | Closed Circuit Television |
| $CO_2$ | Carbon Dioxide |
| DG | Dangerous Good |
| DoP | NSW Department of Planning |
| ERPG | Emergency Response Planning Guidelines |
| HAZOP | Hazard and Operability Study |
| HIPAP | Hazardous Industry Planning Advisory Paper |
| HSE | Health and Safety Executive (UK) |
| IDLH | Immediately Dangerous to Life and Health |
| LPM | Litres Per Minute |
| NOx | Nitrogen Oxides |
| PHA | Preliminary Hazard Analysis |
| ppm | Parts Per Million |
| QRA | Quantitative Risk Analysis |
| SEPP | State Environmental Planning Policy |
| SFARP | So Far As Reasonably Practicable |
| SLOT | Specified Level of Toxicity |
| STEL | Short Term Exposure Limit |
| TPD | Tonnes Per Day |
| TWA | Time Weighted Average |
| VIE | Vacuum Insulated Expander |

# REPORT

# 1 INTRODUCTION

## 1.1 BACKGROUND

Supagas are proposing to expand their carbon dioxide ($CO_2$) production capability by building a new 50 TPD carbon dioxide plant at Bomaderry, NSW.

The plant is to be located on the Shoalhaven Starches site, i.e. adjacent to the Argyle Meats factory that now belongs to the Manildra Group of companies and which Shoalhaven Starches forms part. The site is located at 220 Bolong Road, Bomaderry.

The carbon dioxide feed to the plant will be from the fermentation process on the Shoalhaven Starches site. The carbon dioxide will be purified and liquefied to food grade quality for the food and beverage market.

The proposed plant will have an initial capacity carbon dioxide of up to 50 tonnes per day and then up to 100 tonnes per day when fully operational.

As part of the Project requirements, a Preliminary Hazard Analysis (PHA) is required. Supagas have requested that Pinnacle Risk Management prepare the PHA.

This PHA has been prepared in accordance with the guidelines published by the Department of Planning (DoP) Hazardous Industry Planning Advisory Paper (HIPAP) No 6 (Ref 1).

## 1.2 OBJECTIVES

The main aims of this PHA study are to:

- Identify the credible, potential hazardous events associated with the proposed carbon dioxide facility;
- Evaluate the level of risk associated with the identified potential hazardous events to surrounding land users and compare the calculated risk levels with the risk criteria published by the DoP in HIPAP No 4 (Ref 2);
- Review the adequacy of the proposed safeguards to prevent and mitigate the potential hazardous events; and
- Where necessary, submit recommendations to Supagas to ensure that the proposed facility is operated and maintained at acceptable levels of process safety and effective safety management systems are used.

## 1.3 SCOPE

This PHA assesses the credible, potential hazardous events and corresponding risks associated with the proposed Supagas carbon dioxide facility at Bomaderry with the potential for off-site impacts only.

Off-site transport risks are separately assessed as part of this Project's environmental assessments. The transport of the main hazardous materials, e.g. carbon dioxide, are included in this PHA.

## 1.4 METHODOLOGY

In accordance with the approach recommended by the DoP in HIPAP 6 (Ref 1) the underlying methodology of the PHA is risk-based, that is, the risk of a particular potentially hazardous event is assessed as the outcome of its consequences and likelihood.

The PHA has been conducted as follows:

- Initially, the facility and its location were reviewed to identify credible, potential hazardous events, their causes and consequences. Proposed safeguards were also included in this review;
- The consequences of the potential hazardous events that could have off-site impact were estimated;
- Where the consequential impacts can exceed the criteria in HIPAP 4 (Ref 2) then the likelihood and hence risk were estimated;
- Included in the analysis is the risk of propagation within the site; and
- Assess the risk levels to check if they are within the HIPAP 4 criteria (Ref 2).

## 1.5 RISK CRITERIA

The assessment of risks to both the public as well as to operating personnel from a potentially hazardous development requires the application of the basic steps outlined above. As per SEPP 33 (Ref 3) and HIPAP 6 (Ref 1), the chosen analysis technique should be commensurate with the nature of the risks involved.

The typical risk analysis methodology attempts to take account of all credible hazardous situations that may arise from the operation of processing plants etc. Specific incidents, identified by a variety of techniques, are assessed in terms of consequences and likelihood.

Having assembled data on the credible incidents, risk analysis requires the following general approach for individual incidents (which are then summated for all potential recognised incidents to get cumulative risk):

Risk = Likelihood x Consequence

For QRA and hazard analysis, the consequences of an incident are calculated using standard correlations and probit-type methods which assess the effect of fire radiation, explosion overpressure and toxicity to an individual, depending on the type of hazard.

In this PHA, however, the approach adopted to assess the risk of the identified hazardous events is scenario based risk assessment. The reason for this approach is the limited hazardous events with the potential for off-site harm, i.e. there are generous separation distances involved to sensitive receptors.

Therefore, appropriate analysis of credible scenarios is performed in this PHA. Typically, the consequences of the potential events with off-site impact are assessed first. For the events which do not contribute to off-site risk, as determined by the risk criteria in HIPAP No. 4 (Ref 2), then no further risk analysis is warranted. When the consequence of an event does have the potential to impact people off-site, the likelihood and hence risk is then analysed as required.

The NSW DoP risk criteria applying to developments are summarised in Table 1 below (from Ref 2).

**Table 1 - Risk Criteria, New Plants**

| Description | Risk Criteria |
|---|---|
| Fatality risk to sensitive uses, including hospitals, schools, aged care | $0.5 \times 10^{-6}$ per year |
| Fatality risk to residential and hotels | $1 \times 10^{-6}$ per year |
| Fatality risk to commercial areas, including offices, retail centres, warehouses | $5 \times 10^{-6}$ per year |
| Fatality risk to sporting complexes and active open spaces | $10 \times 10^{-6}$ per year |
| Fatality risk to be contained within the boundary of an industrial site | $50 \times 10^{-6}$ per year |
| Injury risk – incident heat flux radiation at residential areas should not exceed 4.7 kW/m$^2$ at frequencies of more than 50 chances in a million per year or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year | $50 \times 10^{-6}$ per year |
| Toxic exposure - Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure | $10 \times 10^{-6}$ per year |
| Toxic exposure - Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community | $50 \times 10^{-6}$ per year |
| Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m$^2$ or explosion overpressures of 14 kPa in adjacent industrial facilities | $50 \times 10^{-6}$ per year |

# 2 SITE DESCRIPTION

The Shoalhaven Starches factory site is situated on various allotments of land on Bolong Road, Bomaderry, within the City of Shoalhaven (see Figure 1). The factory site, which is located on the south side of Bolong Road on the northern bank of the Shoalhaven River, has an area of approximately 12.5 hectares.

The town of Bomaderry is located approximately 1.1 km to the west of the proposed carbon dioxide plant site and the Nowra urban area is situated 2.1 km to the south west of the site. The suburb Terara is situated approximately 1.3 km to the south of the site across the Shoalhaven River. Pig Island is situated between the factory site and the village of Terara and is currently used for cattle grazing.

There are a number of industrial land uses, which have developed on the strip of land between Bolong Road and the Shoalhaven River. Industrial activities include a metal fabrication factory, the Shoalhaven Starches site, Shoalhaven Dairy Co-op (formerly Australian Co-operative Foods Ltd – now owned by the Manildra Group) and the Shoalhaven Paper Mill (also now owned by the Manildra Group). The nearest industrial neighbour to the proposed carbon dioxide plant is IMEEC (electrical contractors) immediately to the east.

Security of the site will be achieved by a number of means. This includes site personnel and security patrols by an external security company (this includes weekends and night patrols). The site will operate 7 days per week (24 hours per day). Also, the site will be fully fenced and non-operating gates will be locked. Security cameras will be installed for staff to view visitors and site activities.

There will be normally 2 people on site during standard business hours. Outside of standard business hours the plant will be monitored via remote login as well as a remote control room.

The main natural hazard for the site is flooding. No other significant external events are considered high risk for this site.

Location and layout drawings showing the proposed site are shown in Figure 2 and Figure 3.

# Figure 1 – Shoalhaven Starches Location

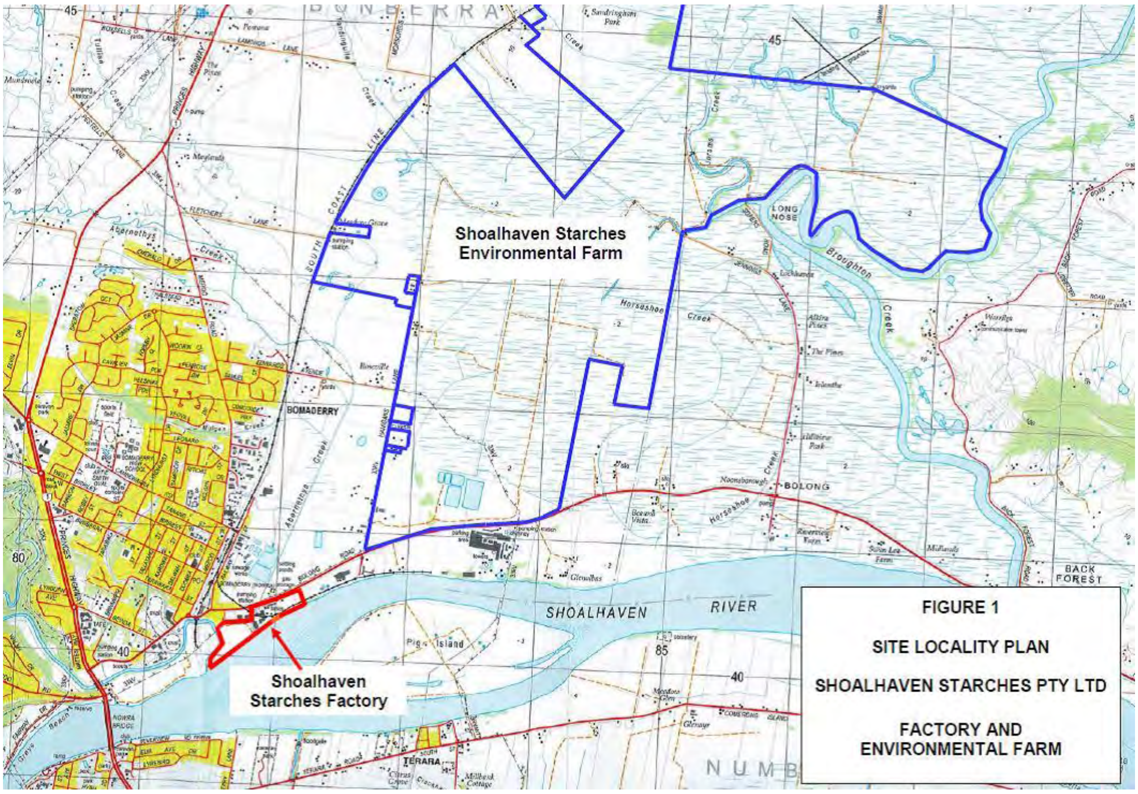
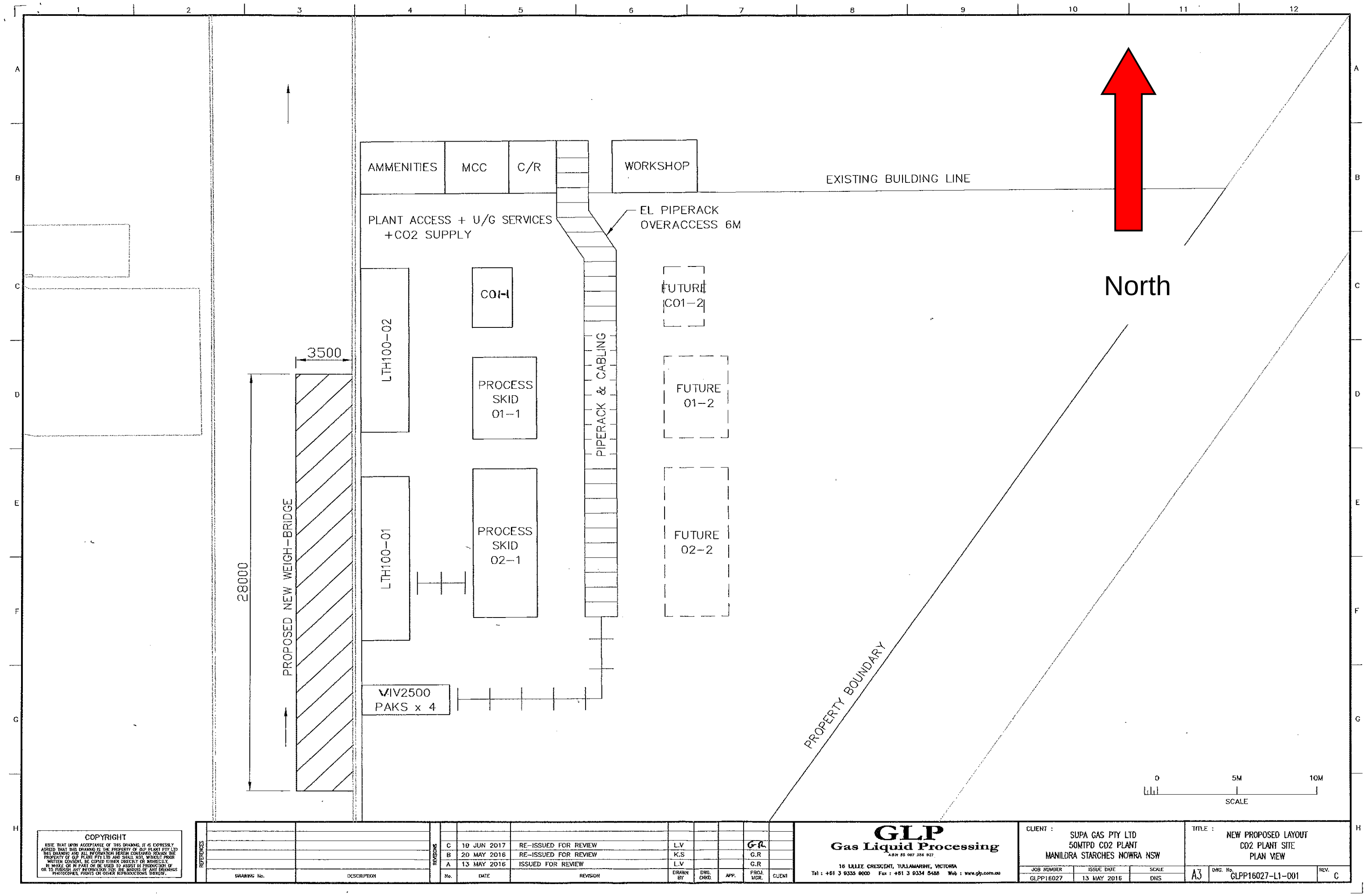


**Figure 2 – Carbon Dioxide Plant Location**


Source: Google Maps

## Figure 3 – Plant Layout



# 3 PROCESS DESCRIPTION

Supagas will take carbon dioxide with a purity of approximately 92 % from the Shoalhaven Starches fermentation system and process this gas into food grade carbon dioxide (>99.99% purity) suitable for food and hospitality markets around Australia.

The plant will have an initial maximum capacity of 50 tonne per day, i.e. Stage 1. The plant capacity will be increased to 100 tonne per day in the future.

The plant feed stream will have the following approximate composition:

- Carbon dioxide 91.7 vol%;
- Oxygen 1.2 vol%;
- Nitrogen 4.3 vol%;
- Water 2.45 vol%;
- Total sulphur 10 ppmv;
- Hydrocarbons 3,120 ppmv; and
- NOx 50 ppmv.

Supagas propose installing the following equipment at the site to enable the carbon dioxide to be purified and liquefied. A process flow diagram is provided in Appendix 1.

- ***Cold Water Scrubber***. This dehumidifies the warm, moist carbon dioxide exiting the Shoalhaven Starches fermentation process and will primarily remove water and alcohol from the feed stream. The scrubber waste stream will be captured and reused by Shoalhaven Starches. The cold water scrubber is to be located on the Shoalhaven Starches site. The resulting carbon dioxide feed stream will be piped (underground) to the Supagas plant. This pipe will be approximately 690 m long and 200 mm nominal diameter.
- ***Carbon Dioxide Compressor***. The carbon dioxide compressor takes the carbon dioxide from the cold water scrubber and raises the pressure to approximately 1,950 kPag.
- ***Sulphide Removal Unit***. Carbon dioxide is fed into the beds that contain an active ingredient which removes any organic sulphides. This active ingredient is removed when spent and sent for disposal at an authorised facility.
- ***CATOX System***. The carbon dioxide is fed through a CATOX system (catalytic oxidation reactor) where the remaining hydrocarbons are oxidised into moisture and carbon dioxide. This system runs at approximately 330 degrees. The reaction process occurs with oxygen in a catalyst filled vessel.
- ***Carbon Dioxide Driers***. The carbon dioxide is further dried to a point where its moisture content is reduced to less than 20 parts per million. This will occur within one of two driers containing molecular sieves, i.e. one drier is on-line whilst the other drier is being regenerated.

- ***Carbon Dioxide Liquefier***. The dried, gaseous carbon dioxide at approximately 1,800 kPag is liquefied in a distillation column and condenser. An ammonia refrigeration system will be used to condense the carbon dioxide (total ammonia capacity of approximately 700 kg).
- ***Carbon Dioxide NOx Removal Vessel***. Liquid carbon dioxide flows through a bed of molecular sieve. The molecular sieves adsorb any NOx. The molecular sieves will be replaced as required and disposed of in accordance with statutory requirements.
- ***Carbon Dioxide Tanks***. The carbon dioxide is then stored in one 100 tonne tank and one 200 tonne tank (providing total storage of 300 tonnes) awaiting despatch.

The carbon dioxide will be transferred (as required) from the tanks into road tankers and then distributed to the market. It is anticipated that there will be two types of road transport:

- A B-double capable of carrying a 30 tonne payload; and
- A single tanker that has a capacity of 20 tonnes.

Stage 1 (i.e the 50 tonne per day plant) will be involve a maximum of 2 truck movements per day and stage 2 (i.e the 100 tonne per day plant) will involve a maximum of 5 truck movements per day. Supagas anticipate all movements occurring during daylight hours.

If the oxygen content in the carbon dioxide feed stream falls below 0.3 vol% then the CATOX system will not work effectively and the carbon dioxide purity will be off-specification. Therefore, there is likely to be backup high pressure oxygen cylinders on site or a liquid oxygen VIE (vacuum insulated expander). Potentially, there could be 5 x 12 packs of oxygen at 124 $m^3$ per pack. This will be used for the CATOX if the oxygen is insufficient in the feedstock.

Wastes from the plant will include:

- Waste water (blowdown) from the cooling towers will be sent to the Shoalhaven Starches waste water treatment plant. This will come from the sump of the cooling tower and is undertaken to prevent total dissolved solids from building up that are naturally present in the water;
- The sulphide beds and NOx removal beds contain absorbents that when spent are sent as trade waste and replaced with new absorbent; and
- The cold water scrubber will remove any residual alcohol and this will be captured and reused by Shoalhaven Starches.

# 4 Hazard Identification

## 4.1 Hazardous Materials

The main hazardous materials involved with the proposed process are:

- Carbon dioxide;
- Oxygen; and
- Ammonia.

There are low concentrations of hydrocarbons in the feed gas (insufficient to make the feed gas flammable though).

### 4.1.1 Carbon Dioxide

Carbon dioxide is a colourless gas with a slightly noticeable odour. It is not flammable or acutely toxic. At high concentrations, it can displace air and is therefore an asphyxiant.

It has a sublimation point of -78°C. In either a liquid or solid form, it has the potential for cold burns.

Carbon dioxide is slightly soluble in water and results in an acidic solution of approximate pH of 4. At elevated temperatures, this solution is corrosive towards some steels, e.g. carbon steel.

Carbon dioxide is a greenhouse gas. It is used in the food industry, e.g. bubbles in soft drinks and beer. The gas is heavier than air and hence may accumulate in confined spaces and pose asphyxiation risks.

The following information on the health impacts from carbon dioxide is from AS2885 (the Australian Standard for Pipelines—Gas and Liquid Petroleum).

**Table 2 – Carbon Dioxide Health Impacts**

| $CO_2$ Concentration | Health Impacts |
|---|---|
| 0.5% | Long-term exposure limit in major jurisdictions |
| 1% | Slightly increased breathing rate |
| 2% | Doubled breathing rate, headache, tiredness |
| 5% | Very rapid breathing, confusion, vision impairment |
| 8 – 10% | Loss of consciousness after 5 to 10 minutes |
| >10% | More rapid loss of consciousness, death if not promptly rescued |

### 4.1.2 Oxygen

Oxygen is not flammable but it strongly supports combustion (i.e. when concentrations are greater than 25%). This includes the combustion of steels as well as soft goods such as plastics and rubbers.

In summary, oxygen promoted fires can occur due to the following main circumstances:

- The presence of hydrocarbons within oxygen systems;
- Adiabatic heat of compression; and
- Velocity related ignitions such as particle impact generating local hot spots.

To minimise the risk of oxygen promoted fires, good design (e.g. choosing the correct materials of construction and restricting velocities through pipes) and good maintenance practices (e.g. dedicated clean rooms for valve and equipment maintenance) are necessary.

Another risk of oxygen involves workers who are exposed to large quantities of the gas. It is possible that clothing can become saturated with oxygen. On ignition, the clothing can spontaneously burn.

Oxygen poses on-site hazards only.

### 4.1.3 Ammonia

Anhydrous ammonia is toxic and flammable (Dangerous Good (DG) Class 2.3 toxic gas). It is a gas at normal temperature and pressure but may be liquefied under moderate pressure (630 kPag at 15$^{o}$C) or at temperatures below -33$^{o}$C at atmospheric pressure.

At low concentrations in air, ammonia vapour irritates the eyes, nose and throat. Ammonia is very soluble in water, therefore as it enters the body, it is readily absorbed. Irritation is immediate and local to the point of entry. Inhalation of high concentrations produces a sensation of suffocation and quickly causes burning of the respiratory tract and may result in death.

Anhydrous liquid ammonia causes severe burns on contact with the skin and if swallowed, it will cause very severe corrosive in the mouth, throat and stomach. Severe eye damage may result from direct contact with the liquid or exposure to high gas concentrations. Long term disability is mainly due to corneal and respiratory injuries.

The exposure limits for ammonia are summarised in the following table.

**Table 3 – Ammonia Exposure Limits**

| Material | Odour Threshold | Exposure Limit (ppm) | | IDLH (ppm) | Injury mechanism |
|---|---|---|---|---|---|
| | | TWA | STEL | | |
| Ammonia | 5 to 53 ppm | 25 | 35 | 300 | Irritant |

Ammonia is flammable in air in a concentration range of 16 - 25% by volume but it does not readily ignite (the minimum ignition energy is 100 mJ, compared with 0.29 mJ for methane). Ignition is therefore difficult and the probability of an explosion in the open air is low. The auto-ignition temperature of ammonia is 651$^{o}$C (relatively high compared to hydrocarbon materials).

Ammonia decomposes into flammable hydrogen gas at approximately 450$^{o}$C.

Given the difficulty of ignition, the relatively narrow flammability range and typical operating conditions, ammonia storage and handling installations are not generally regarded as significant fire or unconfined explosion hazards.

Water spray can be used to absorb vapour releases but should not be sprayed on pools of liquid ammonia as this will cause the liquid to rapidly vaporise (ammonia dissolves exothermically in water). If water is used for vapour absorption, a minimum of 100 volumes of water must be available for each volume of ammonia.

The transport of liquefied ammonia in a tank or bulk container made of quenched and tempered steel is prohibited unless the liquefied ammonia contains not less than 0.2wt% water. Stress corrosion cracking can occur, e.g. due to the presence of oxygen in ppm, if water is not present for these materials of construction.

## 4.2 POTENTIAL HAZARDOUS INCIDENTS REVIEW

In accordance with the requirements of **Guidelines for Hazard Analysis**, (Ref 1), it is necessary to identify hazardous events associated with the facility's operations. As recommended in HIPAP 6, the PHA focuses on "atypical and abnormal events and conditions. It is not intended to apply to continuous or normal operating emissions to air or water".

In keeping with the principles of risk assessments, credible, hazardous events with ***the potential for off-site effects*** have been identified. That is, local events with limited impact or "slips, trips and falls" type events are not included nor are non-credible situations such as an aircraft crash occurring at the same time as an earthquake.

The identified credible, significant incidents with the potential for off-site impacts for the proposed facility are summarised in the Hazard Identification Word Diagram following (Table 4). This diagram presents the causes and consequences of the events, together with major preventative and protective features that are to be included as part of the design.

## Table 4 – Hazard Identification Word Diagram

| Event Number | Hazardous Event | Causes | Consequences | Proposed Safeguards - Prevention Detection Mitigation |
|---|---|---|---|---|
| 1 | Loss of containment of carbon dioxide | Catastrophic pipe failures.<br><br>Catastrophic equipment failures | A large release is required to adversely impact people given the data in Table 2. Smaller releases, when mixed with air in the turbulent jet, result in concentrations at the tip of the jet below 10% and hence unlikely to cause off-site impact or fatality | Piping and equipment to be constructed from Stainless Steel.<br><br>Inspections and test plans for all major equipment items.<br><br>Preventative maintenance of the piping and equipment items |
| 2 | Loss of containment of oxygen | Pipe or equipment failures, adiabatic heat of compression, incompatible materials used within the oxygen system | Potential for enhanced oxygen fires (local impact only).<br><br>Cylinders (if used) may rocket | The oxygen system is to be designed and maintained to AS4041.<br><br>All maintenance work on the oxygen system to be performed by oxygen trained personnel. |
| 3 | Loss of containment of ammonia | Piping or equipment failures, e.g. corrosion, impact, poor weld, fabrication fault<br>Procedural errors, e.g. valve left open | Release of gaseous and/or liquid ammonia. Ammonia, being a toxic gas, can affect people.<br><br>Firewater used to absorb gaseous ammonia will form aqueous ammonia and hence there is a risk to the environment from the alkaline liquid | The ammonia refrigeration system is to be designed to AS1677.<br>Equipment maintenance.<br>Operating procedures for the refrigeration system.<br>Firewater can be used, e.g. via the hydrants, to absorb ammonia gas.<br>Ammonia vessels are to be only isolated for maintenance periods.<br>The ammonia vessels are to be located in an area with low fire hazards |

Given the types of hazardous materials with the potential for off-site impact, i.e. carbon dioxide and ammonia, the main risk is toxic exposure. This is assessed in the following section.

# 5 HAZARDOUS EVENTS ASSESSMENT

## 5.1 CARBON DIOXIDE RELEASES

The impact of concern from carbon dioxide exposure is health; it is not a flammable material. For the risk criteria in Table 1, health impacts of concern are irritation, injury and fatality.

Irritation and injury impacts in residential areas (the closest being 1.1 km away, i.e. Bomaderry) are usually estimated with the AEGL (acute exposure guideline levels) or ERPG (emergency response planning guidelines) values. However, AEGLs and ERPGs are not published for carbon dioxide. This is partly due to the relatively high concentrations required to cause impacts of these types (see Table 2) and hence the relatively short impact distances from a release to these levels. Therefore, irritation and injury impacts from carbon dioxide are not assessed in this PHA.

The important criterion from Table 1 is that the risk of fatality at 50 x $10^{-6}$ per year must remain on the site.

One level of fatal toxicity used by UK HSE (Health and Safety Executive) in relation to the provision of land use planning advice is termed the Specified Level of Toxicity (SLOT). The HSE has defined the SLOT as:

- Severe distress to almost everyone in the area;
- Substantial fraction of exposed population requiring medical attention;
- Some people seriously injured, requiring prolonged treatment; and
- Highly susceptible people possibly being killed.

The SLOT value for carbon dioxide is $1.5 \times 10^{40}$ $ppm^8$.min (provisional value). Hence, for a 1 minute exposure, the required average concentration is 105,200 ppm (or 10.5 vol%), or for a 15 minute exposure, the required average concentration is 75,000 ppm (or 7.5 vol%). The SLOT values are used to determine if fatality at the nearest place of residence and site boundary from a release is possible.

The above SLOT values are consistent with the data in Table 2, i.e. a high carbon dioxide concentration is required to cause fatality.

A 15 minute release duration is taken in this PHA to allow for manual shutdown if a large release occurs. This can involve the Manildra operators who are on-site 24/7, i.e. they can stop the carbon dioxide supply at the fermenters if there is a problem with the carbon dioxide plant.

Scenarios that can cause high carbon dioxide concentrations downwind are:

1. Releases from the 690 m supply pipe to the plant;
2. Releases from the process piping and equipment downstream of the compressors;
3. Catastrophic failure of the storage vessels; and
4. Releases during road tanker transfers.

### 5.1.1 Low Pressure Pipe Releases

Data for long pipeline failures is available from a number of sources but one of the most recent, comparable data set for long underground pipelines is from the UK's Health and Safety Executive (HSE) (Ref 4).

The HSE have researched pipeline releases in the UK over a 45 year period and determined a current failure rate of approximately $2.8x10^{-5}$/yr.km. This is for small, medium and large releases. Note that it is assumed in the HSE data that the pipelines are in use 100% of the time.

Hence, for a 0.69 km pipeline, the failure rate is approximately $1.9x10^{-5}$/yr. As 20 to 60% of pipeline failures are due to third party activities (Ref 5), e.g. construction or farm workers using excavators, and the pipe is to remain on Manildra property then the likelihood of failure is expected to be lower, i.e. in the order of $1x10^{-5}$/yr (or lower).

When the pipe is aboveground at the plant and fed to the compressors, failures can also occur here.

The 100 tpd plant design rate (2,560 sm/hr at 91.7 vol%) is equivalent to 1.2 kg/s of carbon dioxide. This release rate was modelled in TNO's EFFECTS program using the meteorological data shown in Appendix 2 and a ground terrain of regular large obstacles.

The minimum distance to the site's closest boundary is approximately 12 m.

As can be seen from the results in Table 5 (page 17), only the F1.5 condition results in the potential for off-site fatality. The risk associated with this scenario is included in Section 6.

Given the low potential impact from catastrophic low pressure pipe failures at full plant rates then modelling of smaller release sizes is not warranted.

### 5.1.2 Plant (High Pressure) Releases

There are various scenarios for high pressure releases, i.e.:

- Hole in a vessel or pipe with the pressure remaining high; and
- Catastrophic vessel failure, i.e. an instantaneous release.

If the plant continues to run after a catastrophic failure then the release will essentially be the compressor rate, i.e. approximately 1.2 kg/s carbon dioxide, with a low pressure driving force, i.e. the results in Section 5.1.1 will apply. The risk associated with these scenarios are included in Section 6.

***High Pressure Release through a Hole:***

When gases or vapours are released at high pressure, a turbulent jet is formed. This jet draws in a significant quantity of air and hence the concentration within the jet decreases. A good rule-of-thumb is that a turbulent jet draws in at least 10 volumes of air.

This scenario was modelled in EFFECTS using the Turbulent Free Jet model. The distance to 7.5% carbon dioxide is approximately 8.5 m from the point of the release (along the axis). This is for a 50 mm hole at 20 bara (20 C). The release rate is estimated to be approximately 7 kg/s, i.e. higher than the compressor capacity, and hence the plant will depressurise.

Therefore, fatality risk at 12 m or further, i.e. the site's boundary is not predicted.

***Instantaneous Release from a Pressure Vessel Catastrophic Failure:***

The sizing cases for the pressure vessels have yet to be finalised. Therefore, several instantaneous gas releases were modelled in EFFECTS (as dense gas releases).

To potentially cause fatality off-site, the amount of carbon dioxide released instantaneously will need to be approximately 400 kg or larger (i.e. 10 $m^3$ or larger). Other than the storage tanks (assessed separately below), the only vessel likely to contain this quantity of carbon dioxide is the non-condensable stripper column. The results of the instantaneous release modelling are shown in Table 5.

The risk associated with this scenario is included in Section 6.

### 5.1.3 Carbon Dioxide Storage Tank Failures

The liquid carbon dioxide will be stored within two tanks (100 and 300 te capacities). The pressure will be approximately 18 barg (saturation temperature of approximately -22 C). The tanks' volumes are approximately 110 and 330 $m^3$.

When liquid carbon dioxide at saturated conditions is depressurised to ambient pressure, it forms solid carbon dioxide (dry ice) and vapour. The solid carbon dioxide will sublime, over time, with heat ingress.

Given the storage conditions, the percentage of vapour formation when the liquid carbon dioxide is flashed to ambient pressure is approximately 56 wt% (carbon dioxide Mollier Diagram, Planck and Kuprianoff). This flash vapour will combine with the vapour within the tank's ullage to then disperse downwind as a heavy gas.

If average tank level conditions are initially taken for the 100 te tank, i.e. 50% full, then the tank ullage vapour is approximately 0.5 x 110 $m^3$ x 50 $kg/m^3$ = 2,750 kg. When this is combined with the flash vapour, i.e. 50 te x 0.56 = 28 te, then the total cold carbon dioxide vapour instantaneously released is approximately 31 te.

The modelling results of instantaneously releasing 31 te of cold carbon dioxide vapour are shown in Table 5.

As the closest point of the southern tank is approximately 26 m from the nearest site boundary in this analysis then off-site fatality risk is possible for all weather / wind conditions. This conclusion will also be true for releases from the larger tank (300 te).

The risks associated with these scenarios are included in Section 6.

Releases from potential holes in the tanks will form turbulent jets with the same conclusions made in Section 5.1.2, i.e. rapid dilution within the jet and no expected off-site fatality risk.

### 5.1.4 Road Tanker Transfer Releases

There are two main sources of releases during road tanker transfers:

1. Releases from the liquid transfer system; and
2. Vapour releases from the vapour recovery system.

The main causes for these potential releases are failures of the transfer hoses and connections.

A typical transfer rate of 1,500 LPM (approximately 26 kg/s) is assumed for these calculations. As the transfers are supervised by the drivers, emergency response to isolate the leak is expected to be immediate. However, a 10 minute response time is used. This allows for remote as well as local isolation.

***Liquid Releases:***

As discussed in Section 5.1.3, liquid carbon dioxide will flash to dry ice and vapour when released to ambient pressure. The flash vapour is approximately 56 wt%. This equates to 26 kg/s x 0.56 = 15 kg/s vapour for 10 minutes. This is modelled as a dense gas within EFFECTS and the results are shown in Table 5.

The distance from the road tanker transfer point to the nearest property boundary in this analysis is approximately 30 m. Therefore, off-site fatality is not expected.

***Vapour Releases:***

Releases from potential vapour transfer system failures for road tanker loading will form turbulent jets with the same conclusions made in Section 5.1.2, i.e. rapid dilution within the jet and no expected off-site fatality risk.

**Table 5 – Carbon Dioxide Release Modelling Results**

| | Fatality Risk Off-Site (Y/N) (Distance to 7.5%) | | | |
|---|---|---|---|---|
| **Stability Class:** | **Low Pressure Pipe Catastrophic Failures** | **Catastrophic Vessel Failures (10 $m^3$)** | **Tank Catastrophic Failures** | **Liquid Release during Road Tanker Transfers** |
| **A2** | N | N | Y (70 m) | N |
| **B3** | N | Y (13 m) | Y (79 m) | N |
| **C5** | N | Y (16 m) | Y (104 m) | N |
| **D5** | N | Y (16 m) | Y (113 m) | N |
| **E3** | N | Y (13 m) | Y (109 m) | N |
| **F1.5** | Y (22 m) | N | Y (101 m) | N |

Notes for Table 5:

1. The minimum distance from the plant to the nearest property boundary is 12 m (future stage 02-2).

2. The distance from the road tanker transfer point to the same nearest property boundary is approximately 30 m. This point has been chosen as a worst case taking into consideration the probability of wind direction as well as the shortest distance to the plant, i.e. maximum cumulative risk exists at this point.

## 5.2 AMMONIA RELEASES

The impact of concern from ammonia exposure is health. Whilst it is also flammable, it is difficult to ignite in the open. For the risk criteria in Table 1, health impacts of concern are irritation, injury and fatality.

The ammonia refrigeration system at the process plant will hold a relatively small quantity of 700 kg (typically, large industrial refrigeration systems hold an order of magnitude or more ammonia).

During normal operation, the majority of the ammonia will be in liquid form held within the ammonia receiver (approximately 14.5 barg) and the non-condensable stripper column condenser and supply surge drum (approximately ambient pressure, i.e. -33 degrees Celsius). For modelling purposes, it is assumed that approximately 300 kg of liquid ammonia is within each system.

The major potential losses of containment of ammonia can be from:

- Vessel failures; and
- Piping failures.

Smaller releases can also occur from seal or gasket failures and losses of containment when topping up the ammonia charge. The relatively small release diameters for these releases do not pose significant off-site risks.

Ammonia is normally a heavy gas when modelled due to cooling when flashed and also absorption of water from the atmosphere. Therefore, it is modelled with the heavy gas model (SLAB) within EFFECTS.

### *Toxic Impact of Ammonia*

The toxicity effects of ammonia are summarised in Table 6

**Table 6 - Effects of Ammonia**

| Exposure Level (ppm) | Duration (mins) | Effects |
|---|---|---|
| 25 | 60 | ERPG 1 |
| 150 | | ERPG 2 |
| 1,500 | | ERPG 3 |

The three ERPG (emergency response planning guidelines) tiers are defined as follows:

- **ERPG-3** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

- **ERPG-2** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.
- **ERPG-1** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odour.

ERPG 1 (25 ppm) and 2 (150 ppm) are taken as the limits for irritation and injury, respectively.

The above exposure limits are quite conservative given the following information from the Australian Standard (AS2022) for ammonia (Ref 6):

**Up to 100 ppm** – no adverse effect for the average worker with no deliberate exposure for long periods permitted

**400 ppm** – immediate nose and throat irritation with no serious effect after 30 minutes to one hour

**700 ppm** – immediate eye irritation with no serious effect after 30 minutes to one hour

**1,700 ppm** – convulsive coughing, severe eye, nose, and throat irritation; could be fatal after 30 minutes

**2,000-5,000 ppm** – convulsive coughing, severe eye, nose, and throat irritation; could be fatal after 15 minutes

**Over 5,000 ppm** – respiratory spasm, rapid asphyxia and fatal within minutes

The SLOT value for ammonia is $3.78 \times 10^8$ $ppm^2$.min. Hence, for a 1 minute exposure, the required average concentration is 19,440 ppm, or for a 15 minute exposure, the required average concentration is 5,020 ppm. The SLOT values are used to determine if fatality at the nearest site boundary from a release is possible.

**Ammonia Release Cases Modelled**

The following scenarios involving ammonia releases were modelled for the six dominant stability classes and wind speeds in Appendix 2. Concentrations at the nearest residential area and the site boundary are calculated.

1. Catastrophic vessel failures. The release quantity is taken as 300 kg of liquid ammonia (instantaneous release, i.e. exposure time up to 1 minute).

2. Liquid releases from piping and vessel failures corresponding to the various hole sizes (15 minutes duration).

3. Vapour releases from piping and vessel failures corresponding to the various hole sizes (15 minutes duration).

***Scenario 1 – Catastrophic Vessel Failures:***

The results for Scenario 1 above are shown in Table 7. The modelling is performed based on low obstacles as the ammonia plume will largely travel through open country.

The suburb of Terara (situated approximately 1.3 km to the south of the site across the Shoalhaven River) is taken as the residential area of interest as the wind is more dominant from the north when compared to an easterly wind that blows towards the township of Bomaderry, i.e. the results are worst case.

**Table 7 – Ammonia Release Modelling – Catastrophic Failures**

| Stability Class / Wind Speed | Concentration (ppm) at Residential Area (1.3 km) | Concentration (ppm) at the Boundary (12 m) |
|---|---|---|
| A2 | 10 | 400 |
| B3 | 28 | 4,000 |
| C5 | 75 | 40,000 |
| D5 | 20 | 21,000 |
| E3 | - | 1,500 |
| F1.5 | - | 45 |

For the E3 and F1.5 conditions, the vapour will layer without dispersing as far as the other weather / wind combinations. This has been observed with historical releases of liquid ammonia.

Given the results in Table 7 then irritation but not injury is possible at residential areas (B3 and C5 conditions).

For a 1 minute exposure, the required average concentration (SLOT) is 19,440 ppm. This value is exceeded for the C5 and D5 conditions and hence off-site fatality is possible.

The corresponding risks are analysed in Section 6 of this PHA.

***Scenario 2 – Liquid Releases:***

Liquid ammonia releases can occur from the ammonia receiver, the intercooler drum and the ammonia low stage surge drum / $CO_2$ condenser.

The liquid ammonia flowrate to the $CO_2$ condenser is approximately 1,226 kg/hr (0.34 kg/s). This is the highest liquid flowrate within the refrigeration system and requires a relatively small pipe size, e.g. 25 mm or smaller. It is initially assumed that a leak is restricted by this flowrate. The modelling results for this scenario are shown in Table 8.

**Table 8 – Ammonia Liquid Release Modelling**

| Stability Class / Wind Speed | Concentration (ppm) at Residential Area (1.3 km) | Concentration (ppm) at the Boundary (12 m) |
|---|---|---|
| A2 | 1.5 | 260 |
| B3 | 2 | 260 |
| C5 | 3 | 260 |
| D5 | 5 | 260 |
| E3 | 8 | 260 |
| F1.5 | 8 | 255 |

From the results shown in Table 8, off-site irritation and injury are not expected at residential areas and also there is no off-site fatality risk.

However, large hole diameter liquid releases could (for a short time) exceed the design flowrate through the ammonia refrigeration system. These releases could rapidly drain the liquid ammonia from the system.

The estimated leak rates (using EFFECTS) are shown in Table 9.

**Table 9 – Ammonia Liquid Release Rates**

| | Liquid Ammonia Flowrate, kg/s | |
|---|---|---|
| | 50 mm Hole | 25 mm Hole |
| Ammonia Receiver (14.6 barg) | 50 | 12 |
| Intercooler Drum (3.5 barg) | 25 | 6.4 |
| Ammonia Low Stage Surge Drum (approximately 0 barg) | 4 | 1 |

As the inventory of the two main vessels containing liquid ammonia is approximately 300 kg, the 50 mm and 25 mm hole diameter scenarios for the ammonia receiver and intercooler drum are essentially instantaneous failures (normally taken to be a release of 1 minute or less). The results from Table 7 can be used for these scenarios.

As the liquid piping is expected to be relatively small diameter, e.g. 25 mm, then catastrophic pipe failures will yield the same results as a 25 mm hole in a vessel.

The corresponding risks are analysed in Section 6 of this PHA.

Modelling of a 1 kg/s ammonia release (Table 10) shows that off-site impact, i.e. irritation and injury at residential areas and fatality beyond the boundary, are not expected. The results in Table 12 are indicative for the 4 kg/s release rate with the same conclusion, i.e. no significant off-site impacts.

**Table 10 – Ammonia Liquid (1 kg/s) Release Modelling**

| Stability Class / Wind Speed | Concentration (ppm) at Residential Area (1.3 km) | Concentration (ppm) at the Boundary (12 m) |
|---|---|---|
| A2 | 4 | 260 |
| B3 | 4 | 260 |
| C5 | 5 | 260 |
| D5 | 6 | 260 |
| E3 | 7 | 260 |
| F1.5 | 7 | 258 |

### *Scenario 3 – Vapour Releases:*

Ammonia vapour releases can occur from any of the piping or equipment at the three pressure levels within the refrigeration system, i.e. the ammonia receiver, the intercooler drum and the ammonia low stage surge drum.

The estimated vapour leak rates (using EFFECTS) are shown in Table 11.

**Table 11 – Ammonia Vapour Release Rates**

| | Ammonia Vapour Flowrate, kg/s | |
|---|---|---|
| | 50 mm Hole | 25 mm Hole |
| Ammonia Receiver (14.6 barg) | 3.1 | 0.8 |
| Intercooler Drum (3.5 barg) | 1 | 0.2 |
| Ammonia Low Stage Surge Drum (approximately 0 barg) | Note 1 | Note 1 |

Note 1: Flowrate is less than 1 kg/s which has been shown to not cause off-site irritation, injury or fatality risk.

From the modelling in Table 10 for a 1 kg/s ammonia release, off-site impacts, i.e. irritation and injury at residential areas and fatality beyond the boundary, are not expected. Therefore, the corresponding vapour releases can be ignored in the analysis.

Modelling of a 3.1 kg/s ammonia release (Table 12) shows that off-site impact, i.e. irritation and injury at residential areas and fatality beyond the boundary, are not expected.

**Table 12 – Ammonia Vapour (3.1 kg/s) Release Modelling**

| Stability Class / Wind Speed | Concentration (ppm) at Residential Area (1.3 km) | Concentration (ppm) at the Boundary (12 m) |
|---|---|---|
| A2 | 5 | 260 |
| B3 | 5 | 260 |
| C5 | 6 | 260 |
| D5 | 6 | 260 |
| E3 | 6 | 260 |
| F1.5 | 7 | 255 |

## 5.3 Road Transport Incidents

Chemicals transported by road will, where relevant, be transported in accordance with the Australian Code for the Transport of Dangerous Goods by Road and Rail.

The expected frequency and quantity of deliveries of the bulk Dangerous Goods to the site is given in Table 13.

**Table 13 – Bulk Chemicals Road Transport Frequencies**

| Material Transported | Approximate Number of Transport Movements |
|---|---|
| Carbon Dioxide (DG 2.2) | 5 per day |
| Ammonia (DG 2.3, 8) | Note 1 |
| Oxygen (DG 2.2, 5.1) | Note 2 |

Notes:

1. Ammonia deliveries will be infrequent as once the refrigeration is filled, only occasional charging will be required, i.e. to make up for losses.

2. There will potential be no deliveries of oxygen if there is sufficient oxygen within the feed gas to the site.

If a road tanker carrying carbon dioxide is involved in an accident and the vessel integrity is lost then there is the potential for serious injury and fatality for people involved in the accident or those nearby due to asphyxiation.

Causes for road tanker accidents are summarised in Table 14 (Ref 7).

## Table 14 – Causes for Road Tanker Accidents

| Human Error | Equipment Failures | System or Procedural Failures | External Events |
|---|---|---|---|
| • driver impairment, eg. alcohol or drugs<br>• speeding<br>• driver overtired<br>• driver exceeding safe working hours<br>• enroute inspection<br>• contamination<br>• overfilling<br>• other vehicle's driver<br>• taking tight turns/ramps too quickly (overturns)<br>• unsecured loads | • non-dedicated trailer<br>• rail road crossing guard failure<br>• leaking valve<br>• leaking fitting<br>• brake failure<br>• relief device failure<br>• tyre failure<br>• soft shoulder<br>• overpressure<br>• material defect<br>• steering failure<br>• sloshing<br>• high centre of gravity<br>• corrosion<br>• bad weld<br>• excessive grade<br>• poor intersection design<br>• road chamber/width<br>• suspension system<br>• tyre fire caused by friction, brakes overheating or exploding tyres give sparks due to metal in the rubber)<br>• fuel tank fire (diesel) | • driver incentives to work longer hours<br>• driver training<br>• carrier selection<br>• container specification<br>• route selection<br>• emergency response training<br>• speed enforcement<br>• driver rest periods<br>• maintenance<br>• inspection<br>• time of the day restrictions | • vandalism/sabotage<br>• rain<br>• fog/visibility<br>• wind<br>• flood/washout<br>• fire at rest area/parking areas<br>• earthquake<br>• existing accident<br>• animals on road |

The CCPS guidelines (Ref 7) quote a figure of approximately 2 accidents/year (for all causes) per $10^6$ miles, i.e. $1.2 \times 10^{-6}$ accidents per kilometre per year.

Transport studies for NSW roads, e.g. Ref 8, has found the following typical heavy vehicle accident rates for similar road routes:

> 0.016 - 2.96 Heavy Vehicle Accidents/Annual Million km of Heavy Vehicle Travel

In the event of an accident involving a heavy vehicle, the carried goods may or may not be released. The probability of release is dependent on factors such as speed, shipping conditions (i.e. pressurised versus non-pressurised), inadequate load securing, and strength and integrity of the container.

Various studies of release probabilities from heavy vehicles involved in an accident have been undertaken. The **Guidelines for Chemical Transportation Risk Analysis** (Ref 7) indicates that the release probability for various road types is between 5 and 10% (i.e. approximately one heavy vehicle accident in every 10 to 20 will result in a release of the material). The probability of fatality then has to be taken into account but this will depend on factors such as the leak size.

Given the history of road tanker transport in NSW, compliance with the Australian Dangerous Goods Code (an indicator of achieving SFARP (so far as reasonably practicable)) and the above representative data then the risk of an accident involving a vehicle transporting a hazardous material such as carbon dioxide resulting in a release of material is therefore relatively low.

## 5.4 NATURAL AND OTHER EXTERNAL HAZARDOUS EVENTS

The site has been assessed with regard to exposure to the following external hazards:

| | |
|---|---|
| Subsidence | Landslide |
| Burst dam | Earthquake |
| Storm and high winds | Rising water courses |
| Flood | Storm water runoff |
| Lightning | Forest fire |
| Vermin/insect infestation | Security |

Given the proposed location of the site, the significant hazard is flooding. The plant is to be built with to the relevant Australian Standards to mitigate the impact of flooding.

# 6 Risk Analysis

## 6.1 HIPAP 4 Risk Criteria

As discussed in Section 5, the DoP risk criteria of importance for this site are:

- Irritation, injury and fatality risk at a place of residence; and
- Fatality risk to be contained within the boundary of an industrial site, i.e. no more than $50x10^{-6}$/yr.

Given there are a minimal number of materials and events that can cause off-site impact, the analysis in this PHA was done by modelling the carbon dioxide and ammonia release cases for the six dominant stability class / wind directions to determine which events can contribute to off-site risk. The results are shown in Section 55.1.

These results are then analysed using event likelihoods (HSE UK 2012 data used, Ref 9) and the probability that the stability class / wind direction exists. The analysis is shown in Appendix 3 along with further explanation of the assumptions and data sources. The total estimated risks at the worst vase residential area and the nearest site boundary are compared to the HIPAP 4 risk criteria (Ref 2) in Table 15.

**Table 15 – Comparison to HIPAP 4 Risk Criteria**

| Risk Type | HIPAP 4 Criteria | Estimated Risk or Likelihood | Comments |
|---|---|---|---|
| Irritation | $50x10^{-6}$/yr | $2.6x10^{-6}$/yr | Compliant |
| Injury | $10x10^{-6}$/yr | - | Compliant |
| Fatality | $50x10^{-6}$/yr | $7.2x10^{-6}$/yr | Compliant |

The assessment was done on a conservative use of stability class / wind direction data. Therefore, the above estimated risk values are likely to be conservatively high.

## 6.2 Cumulative and Propagation Risk

Given the rural location, the separation distances and that significant consequential impacts largely remain on-site then it is reasonable to conclude that the proposed plant does not make a significant contribution to the existing cumulative risk in the area. Compliance with the HIPAP 4 risk criteria (Table 15) is an indicator of a facility having limited cumulative risk impacts.

There is limited potential for on-site propagation events as the main hazardous events are releases of gas. As carbon dioxide is non-flammable (it is used to extinguish fires), releases will have limited impact (if any) on the adjacent equipment.

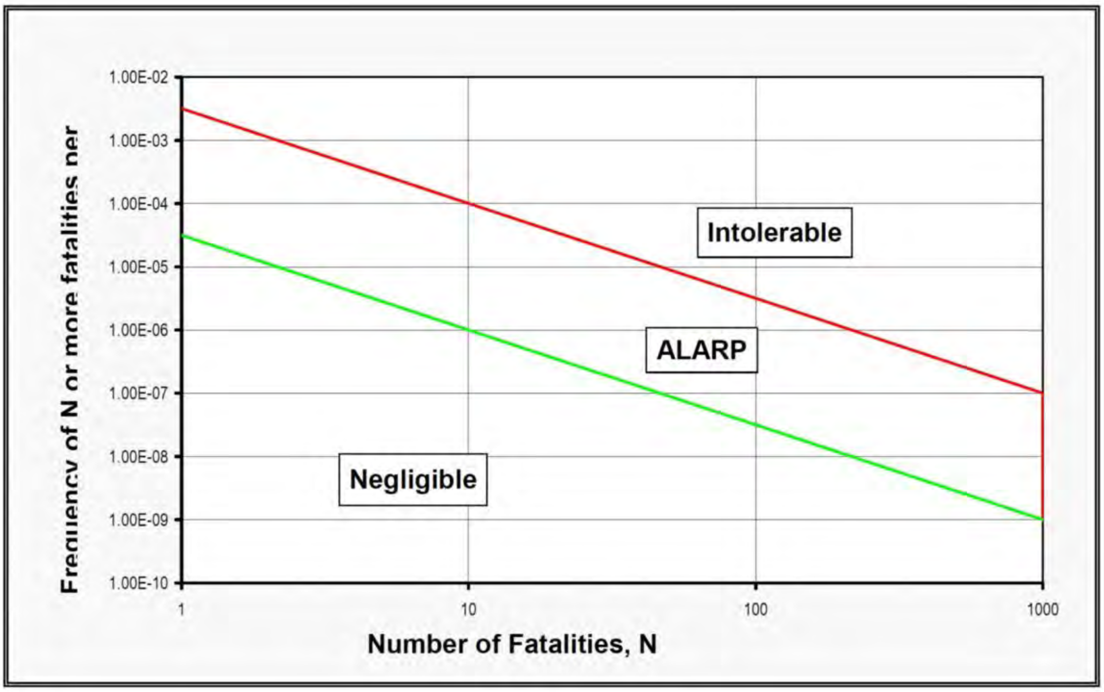
## 6.3 SOCIETAL RISK

Societal risk results are usually presented as F-N curves which show the frequency of events (F) resulting in N or more fatalities. To determine societal risk, it is necessary to quantify the population within each zone of risk surrounding a facility. By combining the results for different risk levels, a societal risk curve can be produced.

Societal risk is normally calculated where the 1 pmpy contour (or calculated risk level) approaches closely to residential areas or sensitive land uses or when events with very large consequence distances are being assessed. Hence, the potential exists for multiple fatalities as a result of a single accident.

The societal risk curve from HIPAP 4 (Ref 2) is shown below.

**Figure 4 – Societal Risk Curve**




From the analysis in Appendix 3, the cumulative frequency for off-site risk is approximately 1 x $10^{-5}$/yr. Given the criteria shown in the above figure, more than 70 fatalities would be required for the risk to be intolerable for all events. Whilst there are industrial facilities to the east and west of the proposed plant, it is not credible that this number of fatalities will occur due to the identified events in this study. Therefore, societal risk is concluded to be acceptable.

Certainly, societal risk at residential and other sensitive types of land users is acceptable.

## 6.4 RISK TO THE BIOPHYSICAL ENVIRONMENT

The main concern for risk to the biophysical environment is generally with effects on whole systems or populations. Whereas any adverse effect on the environment is obviously undesirable, to have an incident with such consequences requires exposure of a sensitive area to either large effect, short term releases or smaller effect, long term releases.

Given the limited number of events that can occur at this site with off-site impacts, the quantity and/or nature of the gases and their relatively low release likelihoods, the risk to biophysical environment is low. This has been shown by analysis in Section 6.1.

In summary, whilst off-site effects can be expected if a major release were to occur, there are no identified whole systems or populations which are at unacceptable levels of risk due to the potentially hazardous events reviewed in this PHA.

## 6.5 Conclusion and Recommendations

The risks associated with the proposed Supagas carbon dioxide plant at Bomaderry have been assessed and compared against the DoP risk criteria.

The results are as follows and show compliance with all risk criteria.

| Description | Risk Criteria | Risk Acceptable? |
|---|---|---|
| Fatality risk to sensitive uses, including hospitals, schools, aged care | $0.5 \times 10^{-6}$ per year | Y |
| Fatality risk to residential and hotels | $1 \times 10^{-6}$ per year | Y |
| Fatality risk to commercial areas, including offices, retail centres, warehouses | $5 \times 10^{-6}$ per year | Y |
| Fatality risk to sporting complexes and active open spaces | $10 \times 10^{-6}$ per year | Y |
| Fatality risk to be contained within the boundary of an industrial site | $50 \times 10^{-6}$ per year | Y |
| Injury risk – incident heat flux radiation at residential areas should not exceed 4.7 kW/m$^2$ at frequencies of more than 50 chances in a million per year or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year | $50 \times 10^{-6}$ per year | Y |
| Toxic exposure - Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure | $10 \times 10^{-6}$ per year | Y |
| Toxic exposure - Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community | $50 \times 10^{-6}$ per year | Y |
| Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m$^2$ or explosion overpressures of 14 kPa in adjacent industrial facilities | $50 \times 10^{-6}$ per year | Y |

Societal risk, area cumulative risk, propagation risk, transport risk and environmental risk are also concluded to be acceptable.

The primary reasons for the low risk levels from the site are the separation distances between the hazards the nearest place of residence and that high levels of carbon dioxide are required to cause fatality.

It is expected that the design review process followed by a HAZOP study will mitigate the generic release cases to acceptable levels. This will include designing the ammonia refrigeration system to the relevant Australian Standards. In addition to the HAZOP study, a significant hazardous event study has been conducted. The results have been included in this PHA as appropriate.

The following recommendations are made from the analysis in this PHA:

1. Ensure that the final design includes means to automatically isolate the carbon dioxide road tanker and storage vessels should a release during a transfer occur (vapour and liquid lines). Actuation should be local as well as remote;
2. Provide CCTV (closed circuit television) coverage of the plant to the Shoalhaven Starches ethanol control room, i.e. these operators control the source of the carbon dioxide;
3. Provide means to suppress an ammonia vapour plume. A plume could occur due to a release from the refrigeration system. Options include using hoses with personnel wearing self-contained breathing apparatus; and
4. Provide alternate emergency assembly areas given that a carbon dioxide plume can travel in any direction.

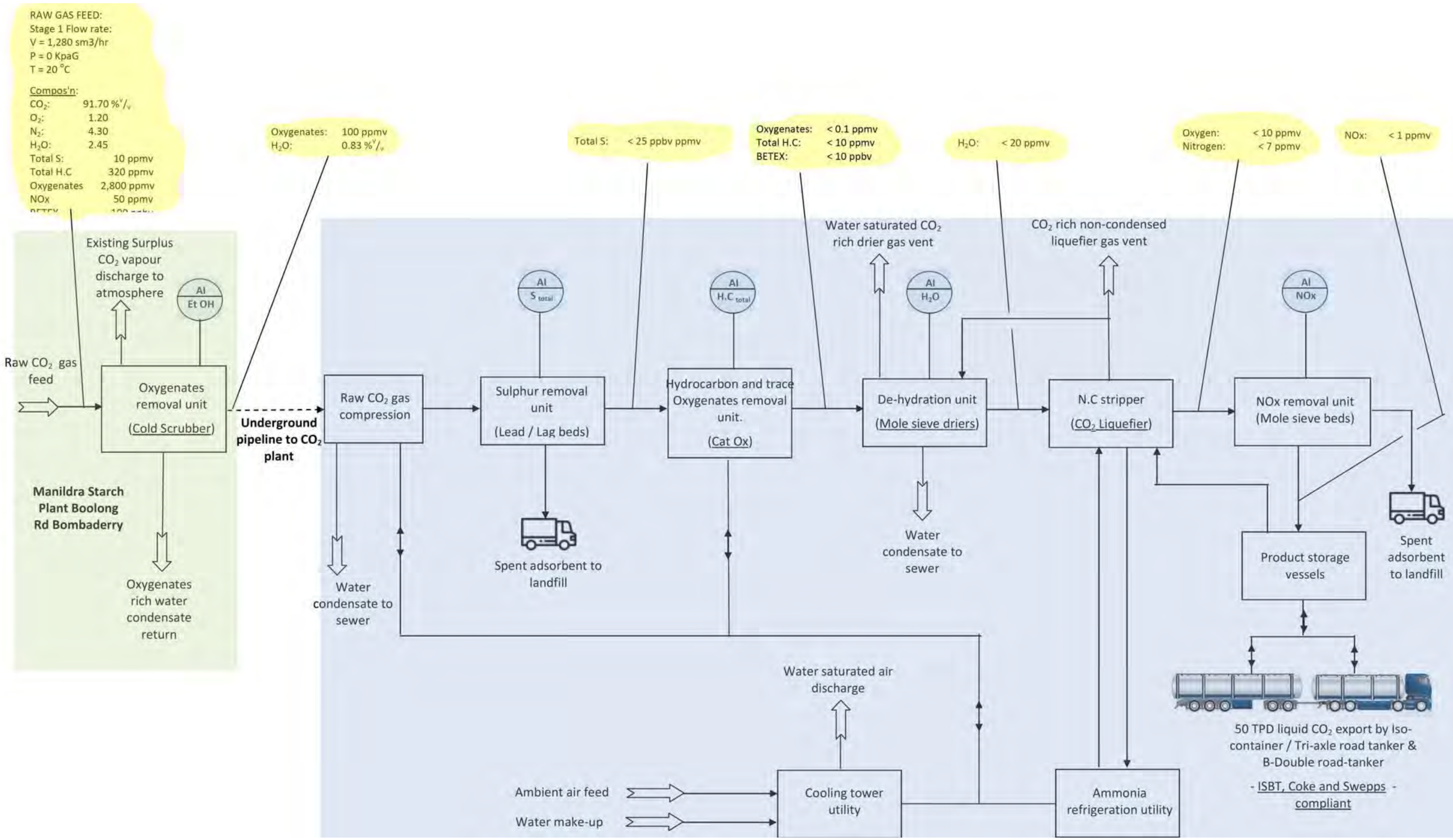
# Appendix 1

# Process Flow Diagram

**Preliminary Hazard Analysis, Carbon Dioxide Plant,**

**Bomaderry**

**Appendix 1 – Process Flow Diagram.**



# Appendix 2

# Meteorological Data

**Preliminary Hazard Analysis, Carbon Dioxide Plant, Bomaderry**

# Appendix 2 – Meteorological Data

The following data is a summary of climate data obtained from the Bureau of Meteorology. The data summarises the local weather / wind conditions for various atmospheric stability classes and wind directions from 2010 to 2017.

| Wind Direction | Stability Class / Wind Speed (m/s) Percentages: | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | **A2** | **B3** | **C5** | **D5** | **E3** | **F1.5** | **Totals:** |
| N | 1.5 | 2.2 | 1.4 | 3.9 | 0.5 | 5.8 | 15.4 |
| NE | 0.5 | 0.7 | 1.4 | 2.7 | 0.2 | 0.2 | 5.6 |
| E | 0.4 | 0.7 | 2.4 | 3.4 | 0.2 | 0.3 | 7.4 |
| SE | 0.3 | 0.6 | 1.6 | 3.6 | 0.2 | 0.5 | 6.8 |
| S | 0.2 | 0.6 | 2.4 | 10.8 | 0.5 | 0.8 | 15.4 |
| SW | 0.1 | 0.2 | 0.7 | 4.5 | 0.8 | 1.2 | 7.6 |
| W | 0.2 | 0.8 | 3.8 | 9.9 | 2.0 | 3.8 | 20.6 |
| NW | 0.6 | 2.0 | 3.9 | 9.3 | 2.3 | 2.9 | 21.1 |
| | | | | | | | |
| Totals: | 3.9 | 8.0 | 17.7 | 48.1 | 6.9 | 15.5 | |

# Appendix 3

# Risk Analysis

**Preliminary Hazard Analysis, Carbon Dioxide Plant, Bomaderry**

## Appendix 3 – Risk Analysis

The risk analysis performed for this PHA is shown on the table below (pages A3.3 and A3.4)

The notes associated with the calculations and shown in the table are:

1. The assumed 30 m low pressure (LP) and 200 m high pressure (HP) pipe lengths are for the 100 tpd option.
2. HSE UK data used for all likelihoods.
3. The number of pressure vessels includes the fixed bed vessels, heat exchangers and the columns for the 100 tpd option.
4. The number of vessels holding up to 300 kg of liquid ammonia is assumed to be two, i.e. there is one ammonia receiver and one ammonia low stage surge drum for the 100 tpd plant.
5. 50 mm and 25 mm holes can occur in the ammonia receiver and intercooler drum in the 100 tpd plant, i.e. two vessels in total, that can result in exceeding the HIPAP 4 criteria.
6. 50 m of piping (containing liquid ammonia) is assumed for the 100 tpd plant.
7. The widths of the plumes were estimated in ALOHA. The probability that the wind is blowing towards the nearest residential area or site boundary is taken to be the plume angle divided by 45 degrees times the probability values for the wind blowing from the direction of interest. Outside of this arc, the plume is not expected to impact the point of interest.

### *Risk Analysis:*

| Scenario | Stability Class Wind Speed | Pipe Length, m | Pipe Failure Likelihood, times/yr.m | Vessels Failure Likelihood, times/yr | Number of Vessels | Event Likelihood, times/yr | Probability of Wind Direction | Contribution to the Following Risks: | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Irritation | Injury | Fatality |
| | | Note 1: | Note 2: | | | | Note 7: | | | |
| Carbon Dioxide - LP Pipe Failures | F1.5 | 30 | 2.00E-07 | | | 6.00E-06 | 0.008 | | | 4.80E-08 |
| | | Note 1: | | Note 2: | Note 3: | | | | | |
| HP Release Through a Hole (with subsequent LP release) | F1.5 | 200 | 5.00E-07 | 4.00E-06 | 34 | 2.36E-04 | 0.008 | | | 1.89E-06 |
| | | | | | | | | | | |
| Stripper Column - Catastrophic Failure | B3 | | | 4.00E-06 | 2 | 8.00E-06 | 0.005 | | | 4.00E-08 |
| | C5 | | | 4.00E-06 | 2 | 8.00E-06 | 0.019 | | | 1.52E-07 |
| | D5 | | | 4.00E-06 | 2 | 8.00E-06 | 0.035 | | | 2.80E-07 |
| | E3 | | | 4.00E-06 | 2 | 8.00E-06 | 0.004 | | | 3.20E-08 |
| | | | | | | | | | | |
| Carbon Dioxide Tanks - Catastrophic Failures | A2 | | | 4.00E-06 | 2 | 8.00E-06 | 0.002 | | | 1.60E-08 |
| | B3 | | | 4.00E-06 | 2 | 8.00E-06 | 0.005 | | | 4.00E-08 |
| | C5 | | | 4.00E-06 | 2 | 8.00E-06 | 0.019 | | | 1.52E-07 |
| | D5 | | | 4.00E-06 | 2 | 8.00E-06 | 0.035 | | | 2.80E-07 |
| | E3 | | | 4.00E-06 | 2 | 8.00E-06 | 0.004 | | | 3.20E-08 |
| | F1.5 | | | 4.00E-06 | 2 | 8.00E-06 | 0.008 | | | 6.40E-08 |
| | | | | | Note 4 | | | | | |
| Ammonia Vessels - Catastrophic Failures | B3 | | | 4.00E-06 | 2 | 8.00E-06 | 0.014 | 1.12E-07 | | |
| | C5 | | | 4.00E-06 | 2 | 8.00E-06 | 0.019 | 1.52E-07 | | 1.52E-07 |
| | D5 | | | 4.00E-06 | 2 | 8.00E-06 | 0.035 | | | 2.80E-07 |
| | | | | | Note 5: | | | | | |
| Ammonia (liquid) - 50 mm Holes | B3 | | | 5.00E-06 | 2 | 1.00E-05 | 0.014 | 1.40E-07 | | |
| | C5 | | | 5.00E-06 | 2 | 1.00E-05 | 0.019 | 1.90E-07 | | 1.90E-07 |
| | D5 | | | 5.00E-06 | 2 | 1.00E-05 | 0.035 | | | 3.50E-07 |
| | | | | | Note 5: | | | | | |
| Ammonia (liquid) - 25 mm Holes | B3 | | | 5.00E-06 | 2 | 1.00E-05 | 0.014 | 1.40E-07 | | |
| | C5 | | | 5.00E-06 | 2 | 1.00E-05 | 0.019 | 1.90E-07 | | 1.90E-07 |
| | D5 | | | 5.00E-06 | 2 | 1.00E-05 | 0.035 | | | 3.50E-07 |

| Scenario | Stability Class Wind Speed | Pipe Length, m | Pipe Failure Likelihood, times/yr.m | Vessels Failure Likelihood, times/yr | Number of Vessels | Event Likelihood, times/yr | Probability of Wind Direction | Contribution to the Following Risks: | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Irritation | Injury | Fatality |
| | | Note 6: | | | | | | | | |
| Ammonia (liquid) - 25 mm Pipe Failures | B3 | 50 | 1.00E-06 | | | 5.00E-05 | 0.014 | 7.00E-07 | | |
| | C5 | 50 | 1.00E-06 | | | 5.00E-05 | 0.019 | 9.50E-07 | | 9.50E-07 |
| | D5 | 50 | 1.00E-06 | | | 5.00E-05 | 0.035 | | | 1.75E-06 |
| | | | | | | | | | | |
| **Totals:** | | | | | | | | **2.57E-06** | **0.00E+00** | **7.24E-06** |

# 7 REFERENCES


1 Department of Planning and Infrastructure (NSW) **Hazardous Industry Planning Advisory Paper No 6 – Hazard Analysis,** January, 2011

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