Appendix D Preliminary Hazard Analysis

Bulk Liquids Berth No. 2 – Port Botany

PRELIMINARY HAZARD ASSESSMENT

- Final
- 12 November 2007

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EXECUTIVE SUMMARY

Introduction, Objectives and Scope

Vopak Terminals Sydney Pty Ltd (Vopak) is proposing, on behalf of the Sydney Ports Corporation (SPC) to obtain approval for the construction and operation of a second Bulk Liquids Berth (BLB2) facility at Port Botany NSW. The proposed Bulk Liquids Berth No. 2 (BLB2) will be a shared facility and will be administered by SPC. The project will consist of the following:

- Construction of a steel piled pier berth adjacent to the existing BLB1 parallel to the privately accessed Fishburn Road (approximately at the boundary between Vopak Site B and Elgas Caverns);
- Installation of associated infrastructure such as Marine Loading Arms (MLA) and fire fighting equipment; and
- Installation of additional pipelines from existing user sites to the new berth.

BLB2 is proposed to handle the predicted increase in chemical, petroleum and gas products to be transferred at Port Botany and to reduce the demurrage costs which some customers are currently incurring due to operational limitations and scheduling conflicts. The proposed new berth would also allow the capacity to remain ahead of demand and ensure New South Wales has an efficient and competitive facility in comparison with other Australian ports.

To ensure the appropriate safety provisions are made for the facility, a preliminary hazard analysis (PHA) is required as part of the Director General's requirements. Vopak has commissioned Sinclair Knight Merz to conduct the PHA study of the site.

The objectives are to conduct a PHA study of the proposed BLB2 project, using the Hazardous Industry Planning Advisory Paper (HIPAP) No.6 guidelines (Ref.12) and to determine whether assessed risks impact the existing risk contours developed for the Port Botany area in the Port Botany Land Use Safety Study (Ref.1). The scope of work is for the assessment of the BLB2 impacts on the existing risk contours only. The study does not include the assessment of other facilities in the Port Botany Area.

Methodology

The methodology used for the study was that described in the Multi-Level Risk Assessment approach, published by the NSW Department of Planning (Ref.2). The approach used the following steps:

- **Hazard Analysis** – identify those hazards that have the potential to impact the existing risk contours for the Port Botany Area;
- **Consequence Analysis** – assess the consequence impacts of the identified hazards and eliminate those incidents that have no consequence impacts on the existing contours, carry forward for further analysis those incidents with impacts to existing contours;

- **Frequency Analysis** – assess the frequency of those incidents identified to have a potential impact on the existing contours, carry these results forward for risk analysis;
- **Risk Analysis & Review** – combine the consequence and frequency results to determine the risks, compare the risks to the existing contours and determine whether there are any incidents that could result in contour extension. Apply risk reduction to those incidents identified to impact contours and review risks. Continue this process until there is no impact on contours.

Brief Description of the BLB2 Facility

The proposed BLB2 facility will be constructed on the western side of the Port Botany peninsular, south of the existing BLB1 facility. The wharf will have a single deck 76m long by 32m wide. Five marine loading arms (MLAs) will be installed on the wharf, four for petroleum products and one for LPG. Two chemical transfer manifolds will also be installed on the northern section of the deck to facilitate chemical transfers as required.

The deck will also be constructed with a hose storage shed and a small operator's shed. Three fire monitors will also be installed on the wharf deck. These monitors will be remote control operated from the shore to facilitate operation without approaching a hazard.

Ships will come alongside the wharf with the assistance of tugs. Once moored, the relevant safety checks will be performed and the flexible hose (chemicals) or MLA will be connected to the ships manifold (bolted connection). Only 1 MLA will be used for the transfer of LPG and up to 4 MLAs, simultaneously, for the transfer of flammable/ combustible liquids. Up to 8 flexible hoses can be connected simultaneously for the transfer of chemicals (toxic, corrosive, flammable and combustible), however, it is unlikely that hoses and MLAs will be used simultaneously. A pressure test will then be conducted with nitrogen at 800kPa for liquids and 900kPa for gases. The product will then be transferred via the specific pipeline to the user's facility/storage. On completion of the transfer, all pipelines will be purged and will rest empty until the next required use.

Hazard Identification

A hazard identification workshop was conducted to identify those hazards that could result in impacts to the existing risk contours for the BLB2 area. The following hazards were identified:

- Ship strikes the wharf at excessive speed;
- Moored ship is struck by passing ship;
- Chemical hose failure leading to release of chemicals;
- Chemical pipeline failure leading to release of chemicals;
- Marine loading arm failure leading to flammable gas release;
- Liquefied Flammable Gas (LPG) pipeline failure leading to flammable gas release;
- Marine loading arm failure leading to flammable liquid release;
- Flammable liquid pipeline failure leading to flammable liquid release; and

- Mooring systems fail leading to ship moving away from the wharf and breaking transfer connections.

Each hazard was assessed for potential to impact the existing contours. Those incidents identified to have no potential to impact the existing risk contours were not assessed further in the study. A list of hazards was then developed and carried forward for consequence analysis.

Consequence Analysis

After detailed hazard assessment, the following hazards were identified to have a potential to impact the existing risk contours for the Port Botany area:

- LPG Transfer MLA Failure – leak/release, ignition and explosion/fire;
- LPG Pipeline Failure – leak/release, ignition and explosion/fire;
- Flammable/Combustible Liquid MLA Failure – leak/release, ignition and fire;
- Flexible hose failure (rupture) – flammable/combustible liquid release, ignition and fire;
- Flammable/Combustible Liquid Pipeline Failure - leak/release, ignition and fire;

Each incident was subjected to a detailed consequence analysis. It was identified that each incident has a number of sub-incidents, for example, a release of LPG at a flange could result in an immediate jet fire, a flash fire or explosion. The consequence analysis identified that the severity of some incidents was not sufficient to impact the existing risk contours, hence, these incidents were eliminated from further analysis. A list of incidents was then developed and carried forward for frequency analysis.

Frequency Analysis

The following incidents were carried forward for frequency analysis:

- Environmental Impact – flexible hose failure (chemical transfer);
- Jet fire – MLA catastrophic failure (LPG);
- Flash Fire – MLA catastrophic failure (LPG);
- Jet Fire – flange leak isolating valve station (LPG);
- Jet Fire – valve leak isolating valve station (LPG);
- Flash Fire – flange leak isolating valve station (LPG);
- Flash Fire – valve leak isolating valve station (LPG);
- Pool Fire – flange leak isolating valve station (flammable/combustible liquid); and
- Pool Fire – valve leak isolating valve station (flammable/combustible liquid).

Each incident was subjected to a frequency analysis to determine whether the frequency of the event was high enough to cause impact to the existing risk contours for the site. The frequency of incidents was then carried forward for risk assessment.

Risk Assessment and Review

Table 1-1 shows a summary of the fatality probability as a result on incidents, the incident frequency and the risk.

Table 1-1 Summary of Fatality Probability, Incident Frequency and Risk Results

Incident	Fatality Probability[1]	Incident Frequency[2]	Risk[3] (pmpy)
Jet Fire-MLA Rupture (LPG)	1	$2.6x10^{-7}$p.a.	0.26
Flash Fire – MLA Rupture (LPG)	1	$2.6x10^{-7}$ p.a.	0.26
Jet Fire – flange leak isolating valve station (LPG)	0.35	$1.3x10^{-7}$ p.a.	0.045
Jet Fire – valve leak isolating valve station (LPG)	0.35	$2.16x10^{-6}$ p.a.	0.76
Flash Fire – flange leak isolating valve station (LPG)	1	$1.3x10^{-7}$ p.a.	0.13
Flash Fire – valve leak isolating valve station (LPG)	1	$2.16x10^{-6}$ p.a.	2.16
Pool Fire – flange leak isolation valve station (Flammable/Combustible Liquid)	0.48	$2.06x10^{-5}$ p.a.	10
Pool Fire – valve isolation valve station (Flammable/Combustible Liquid)	0.48	$1.3x10^{-5}$ p.a.	6.24

Notes: 1. see **Table 5-1**
2. Summarised from Section 6
3. Multiple of Fatality probability and incident frequency (per million per year – pmpy)

Conclusions

Cumulative Risks for Incidents at the MLA

The two incidents described in **Table 1-1**, relating to the MLA risks, each have a risk of 0.26pmpy. Hence, the total risk (cumulative) is 0.26 x 2 = 0.52pmpy. This occurs at the existing 50pmpy contour that currently surrounds the proposed BLB2 facility in the Port Botany study (Ref.1). Hence, it is concluded that there would be negligible impact on the existing 50pmpy contour or the 1pmpy contour a further 30m beyond the 50pmpy contour.

Cumulative Risks for Incidents at the Pipeline Isolating Valve Station

There were six incidents identified at the pipeline isolating valve station. The cumulative risk is the summation of the risk values in **Table 5-1**, which is 19.3pmpy. This risk impact occurs at the existing 50pmpy contour that currently surrounds the BLB2 facility in the Port Botany study (Ref.1). Hence, it is concluded that there would be no increase to the existing 50pmpy contour or the 1pmpy contour a further 130m into Botany Bay.

Risk Impacts to Adjacent Industrial Facilities

In addition to the assessment of impacts of the proposed BLB on the existing risk contours, the individual fatality risk at the closest industrial facility (Elgas) was assessed. It was identified that the fatality risk at this facility, as a result of the proposed BLB2 operation would be less than 19.3 pmpy. This is below the acceptable risk criteria of 50 pmpy for industrial sites. Hence, it is concluded that the proposed BLB would only be classified as potentially hazardous and not actually hazardous under the definition detailed in State Environmental Planning Policy No.33.

Recommendations

Notwithstanding the assessment conducted in the study a number of recommendations have been made to ensure the risks are maintained within the as low as reasonably practicable (ALARP) range. The following recommendations are made:

1) It was identified that leaks of flammable liquid or chemicals into the pipeline isolation valve pit (at the shore line) could result in the pit filling and overflowing to the bay close by. It is therefore recommended that consideration be given to installing a level alarm switch at the isolation valve pit to detect any leaks and alarm at the transfer control room.
2) It was identified that leaks of LPG near the valve pit could result in the pit filling with LP gas. In the event an ignition of the gas occurs, an explosion could result leading to pipeline and valve damage and further release of products (domino incident). It is therefore recommended that the gas isolation valves at the shoreline be separated from the other isolation valves and located away from the pit (i.e. flammable liquids and chemicals) to eliminate the potential for any leaks to accumulate in the pit.

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ABBREVIATIONS AND TERMS

Abbreviation/Term	Description
ALARP	As Low As Reasonably Practicable
AS	Australian Standard
BLB	Bulk Liquids Berth
CFG	Compressed Fibre Gasket
DG	Dangerous Goods
DoP	Department of Planning
Double Bottom	A void section of the ship between the hull and tank
EA	Environmental Assessment
ESD	Emergency Shut Down
HIPAP	Hazardous Industry Planning Advisory Paper
IMDG	International Maritime Dangerous Goods
ISGOTT	International Safety Guide for Oil Tankers & Terminals
kPa	kilo Pascals
kW/m^2	kilo Watts per square metre
LPG	Liquefied Petroleum Gases
M	Metres
MLA	Marine Loading Arm
OREDA	Offshore Reliability Data
p.a.	per annum
PG	Packaging Group
PHA	Preliminary Hazard Analysis
Pmpy	per million per year
QRA	Quantitative Risk Assessment
SCADA	Supervisory Control & Data Acquisition
Scupper	A drain on the deck of the ship that discharges overboard
SEPP	State Environmental Planning Policy
SPC	Sydney Ports Corporation
SWG	Spiral Wound Gasket
Taxonomy	A reference number for reliability data sheets

1. INTRODUCTION

1.1 Background

Vopak Terminals Sydney Pty Ltd (Vopak) is proposing, on behalf of the SPC to obtain approval for the construction and operation of a second Bulk Liquids Berth (BLB2) facility at Port Botany NSW. The proposed Bulk Liquids Berth No. 2 (BLB2) will be a shared facility and will be administered by Sydney Ports Corporation (SPC). The project will consist of the following:

- Construction of a steel piled pier berth adjacent to the existing BLB1;
- Installation of associated infrastructure such as marine loading arms (MLA) and fire fighting equipment;
- Installation of additional pipelines from existing user sites to the new berth; and
- Unloading/ loading and maintenance activities associated with the operation of the facility.

BLB2 is proposed to handle the predicted increase in imported chemical, petroleum and gas products into Port Botany and to reduce the demurrage costs which customers are currently incurring due to operational limitations and scheduling conflicts. The proposed new berth would also allow the capacity to remain ahead of demand and ensure New South Wales has an efficient and competitive facility in comparison with other Australian ports.

To ensure the appropriate safety provisions are made for the facility, a preliminary hazard analysis (PHA) is required as part of the Director General's requirements. Vopak has commissioned Sinclair Knight Merz to conduct the PHA study of the site.

This document details the objectives, scope of works, methodology, results, conclusions and recommendations for the Botany BLB2 project.

1.2 Objectives

The objectives of the study are to:

- Conduct a PHA study of the proposed BLB2 project in accordance with the requirements of Hazardous Industry Planning Advisory Paper No.6, Guidelines for Hazard Analysis;
- Identify whether the proposed BLB2 facility will impact on the existing risk contours for the Port Botany Area (Ref.1); and
- Report on the findings of the study for inclusion in the Environmental Assessment (EA).

1.3 Scope of Works

The scope of works is for a PHA study of the BLB2 facility at Port Botany, NSW. The study includes the assessment of hazards and risks associated with the operation of the proposed berth. The scope does not include assessment of any existing facilities at the bulk liquids berth site.

2. METHODOLOGY

2.1 General Approach

The NSW Department of Planning (DoP) Multi Level Risk Assessment (Ref.2) approach was used for this study. The approach considered the development in context of its location and its technical and safety management control. The Multi Level Risk Assessment Guidelines are intended to assist industry, consultants and the consent authorities to carry out and evaluate risk assessments at an appropriate level for the facility being studied.

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

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

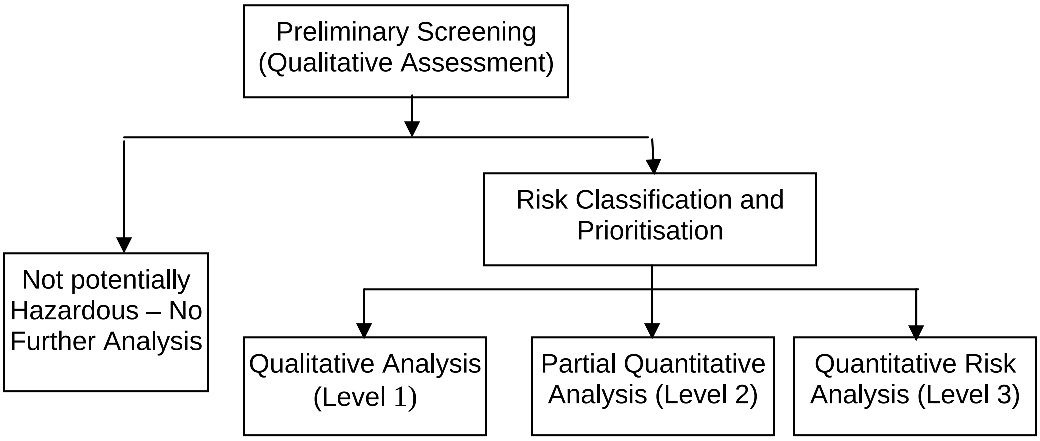


Figure 2-1 The Multi Level Risk Assessment Approach

The document "Applying SEPP 33" (Ref.3) guideline may also be used to assist in the selection of the appropriate level of assessment. This guideline states the following:

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

- *where materials are relatively non-hazardous (for example corrosive substances and some classes of flammables);*
- *where the quantity of materials used are relatively small;*

- *where the technical and management safeguards are self-evident and readily implemented; and*
- *where the surrounding land uses are relatively non-sensitive.*

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

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

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

The proposed BLB2 facility will be located on the end of the Port Botany peninsular and within an industrialised port area. Sensitive land users are well clear of the site, the closest residential buildings being over 1.7kms to the east (Matraville/Phillip Bay area). Detailed technical and management safeguards are currently used at the existing BLB and these will be implemented at the proposed BLB2. An assessment of the BLB2 project was undertaken as part of the Port Botany Land Use Safety Study (Ref.1) using a quantitative approach and therefore a qualitative study is not considered appropriate for the proposed BLB2 assessment.

As the Port Botany Land Use Safety Study used a quantitative approach, the analysis for the BLB2 study in this document will also be quantitative in nature. A key component of the Director General's Requirements (DGRs) is a review of the impact of the proposed facility on the existing contours developed for the Port Botany Land Use Safety Study. Hence, the selected approach for this study will be to assess the risks associated with the operation of the proposed BLB2 facility and to compare these to the existing risk contours developed in the Port Botany Land Use Safety study. In the event assessed risks exceed the existing contours, risk reduction measures will be developed and recommended as part of this study.

The following detailed risk assessment approach will be used, which is based on the HIPAP No.6 guidelines.

2.1.1 Hazard Identification

.A hazard identification workshop was held with the stakeholders in the BLB2 development and operation. The results of the study were used to develop a Hazard Identification table for use in the consequence, frequency and risk assessment.

2.1.2 Consequence Assessment

The identified hazards, listed in the Hazard Identification Table were subjected to a consequence assessment. Where hazards could be quantified for impact to people, the impact severity was assessed and carried forward for frequency analysis. Where impacts to the environment were identified, release quantities were estimated and carried forward for frequency analysis.

2.1.3 Frequency Assessment

Those incidents carried forward from the consequence analysis were subjected to a frequency analysis. This involved the assessment of the initiating event (i.e. leak) and then the application of the probability of failure of the protection systems. Fault and event trees were used to assess the final event frequency.

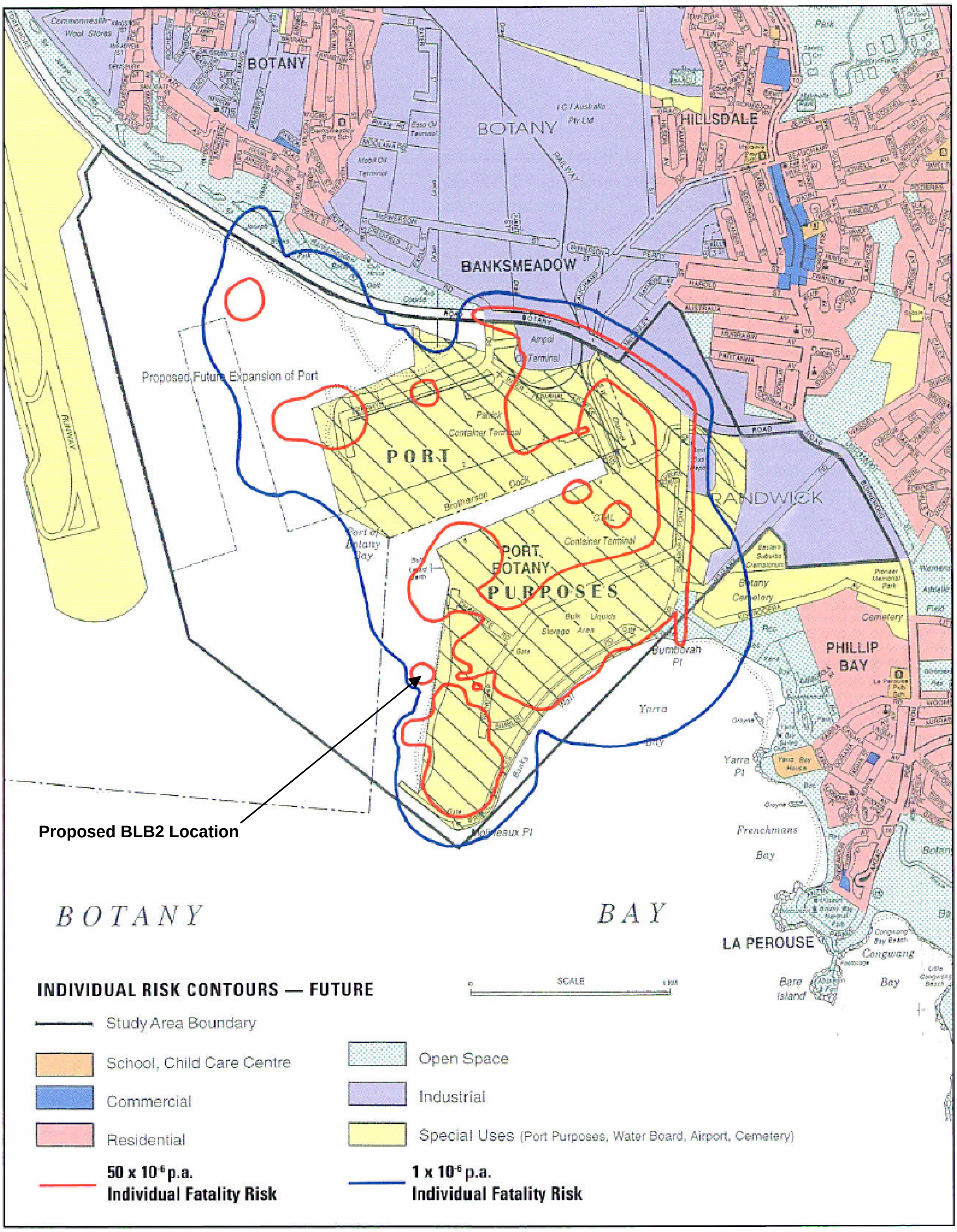
2.1.4 Risk Assessment and Review

The existing risk contours (see **Figure 2-2**) were used to determine selected points for which risk was assessed. For example, the location of the closest point on the fatality risk contour to the south of the site was selected and the distance to this point used to determine the cumulative impacts and risks at this location from the operations at the BLB2 facility. The assessment results were then compared to the risk contour value to determine whether the existing value was exceeded.

Where the results of the assessment did not exceed the risk contour value, no further assessment was conducted. Where risk contour values were exceeded, the major risk contributors were identified and risk reduction was applied to these. The risks were then reviewed to ensure the applied risk reduction was successful in reducing the risks by the required amount.

2.1.5 Reporting

On completion of the study, a draft report was developed for review by the stakeholders. Comments on the draft were then incorporated and a final report issued for inclusion in the EA.



(Ref.1)

Figure 2-2 Cumulative Individual Risk Contours including Postulated Future Development (i.e. BLB2)

3. BRIEF DESCRIPTION OF THE BLB2 FACILITY AND OPERATION

3.1 Surrounding Land Uses

The proposed BLB2 will be constructed south of the existing BLB1 facility, at the south-western end of Brotherson Dock, Port Botany, NSW. **Figure 3-1** shows the Port Botany regional location. The site will be accessed from the main Botany area via Simblist Road, privately accessed Fishburn Road and Charlotte Road. The BLB site is located in an industrialised area zoned 4b (Port Botany) and is surrounded by a number of bulk liquid storage facilities, wharves and docks. The closest residential area is located about 1.7kms to the east (Matraville/Phillip Bay Area). **Figure 3-2** shows an aerial photograph of the Port Botany area, showing the location of the BLB facilities in relation to the surrounding land uses.

The following land uses surround the BLB site:

- North – Patricks Container Terminal (across Brotherson Dock);
- East – Elgas surface facilities for underground bulk LPG storage, Vopak bulk liquids storage, Fishburn Road and Qenos bulk liquids storage;
- South – Molineux Point (end of Port Botany peninsular) and Botany Bay; and
- West – Botany Bay

There are no sensitive land users close to the proposed BLB site. The closest school to the facility (La Perouse Primary School) is located about 2.5kms from the proposed berth.

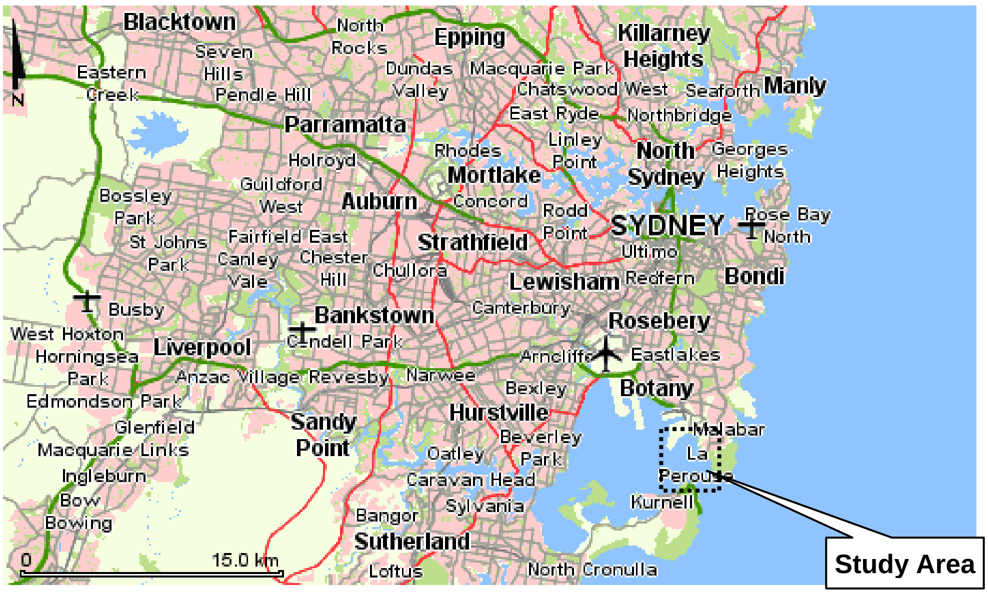


Figure 3-1 Port Botany Regional Location

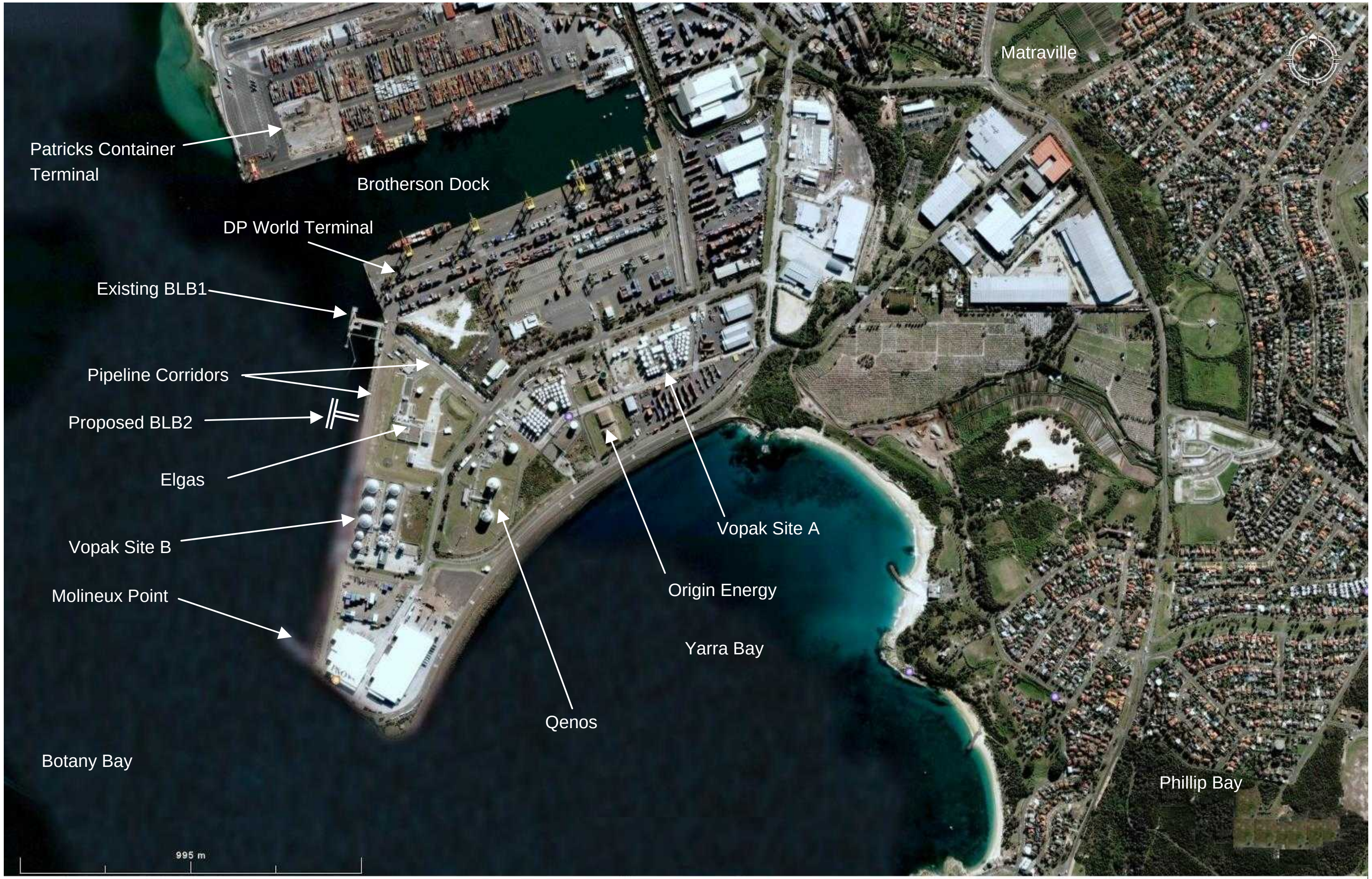
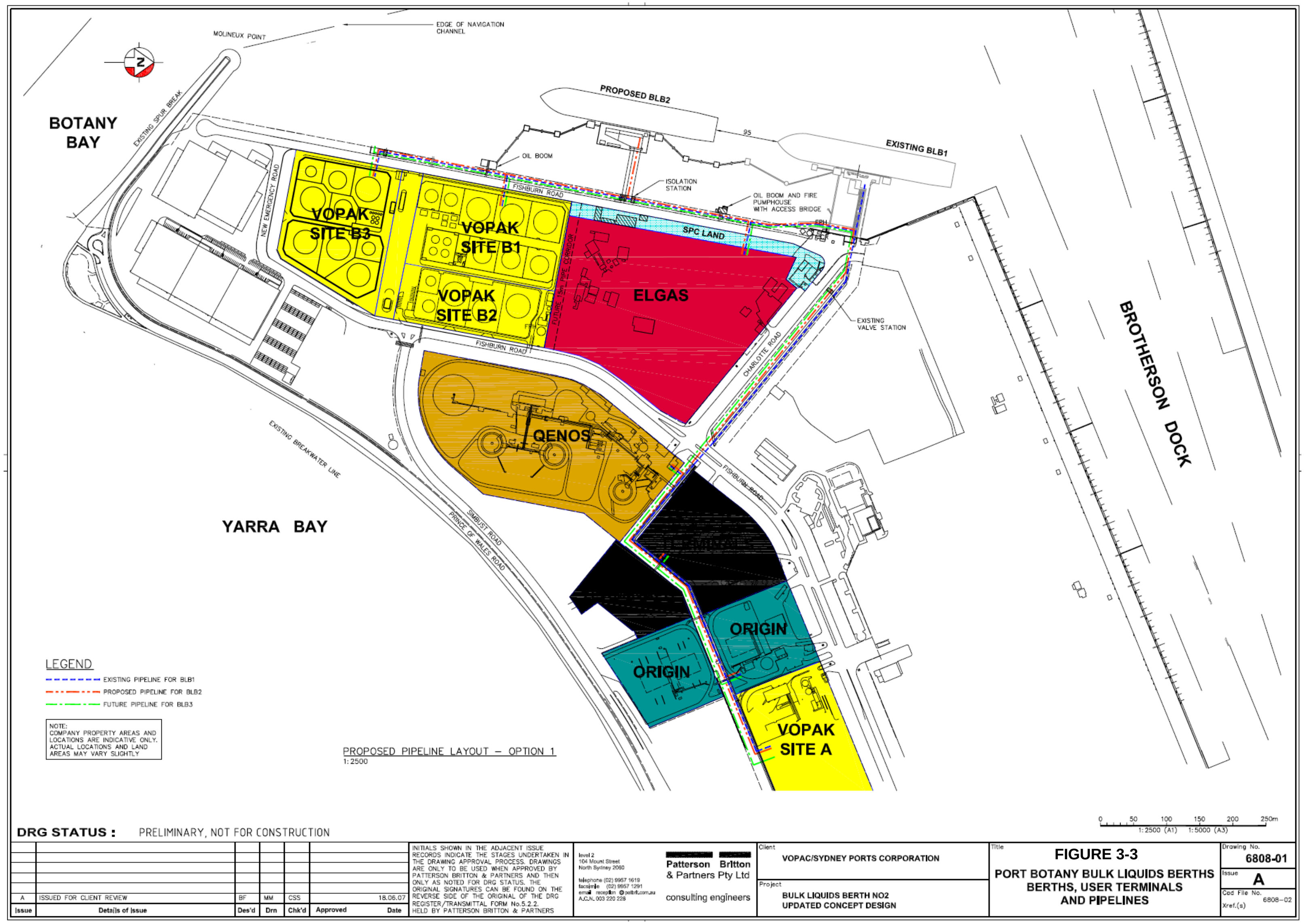


Figure 3-2 Aerial photograph of Port Botany showing BLB2 and surrounding land uses



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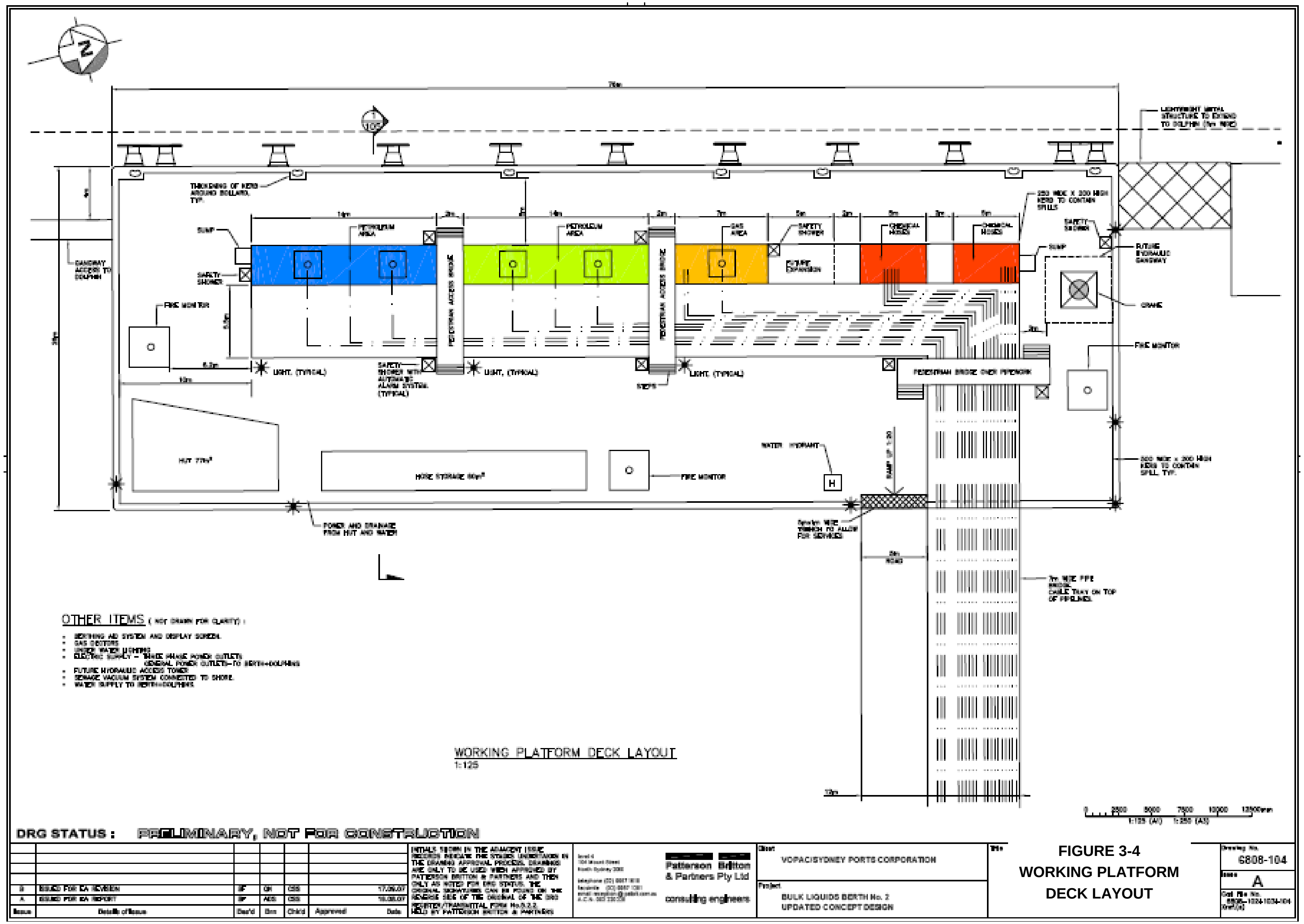

FIGURE 3-4
WORKING PLATFORM
DECK LAYOUT

3.2 Background & General Site Description

The existing Bulk Liquids Berth (BLB1) at Port Botany is nearly 30 years old and is heavily utilised by the bulk liquids industry. A second bulk liquids berth (BLB2) is required to meet increasing demand.

The existing BLB1 is located in Botany Bay at the south-western end of Brotherson Dock, Molineux Point, Port Botany, approximately 11 km south of the Sydney CBD (**Figure 3-1)**. BLB1 was commissioned in 1979 as a common-user facility and currently handles hazardous and non-hazardous bulk liquids and gases which are transferred by pipeline to nearby industries.

The demand for bulk liquids imported and exported through the existing bulk loading berth (BLB1) has grown significantly in recent years. Berth utilisation at BLB1 varies and although currently it is less than the accepted maximum of 65%, (or between 200-250 occupancy days per year), demurrage charges are currently being incurred by the existing users of the berth due to scheduling conflicts and operational limitations.

A second berth bulk liquids berth (BLB2) is proposed to cater for the growth. **Figures 3-2, 3-3** & **3-4** show the detailed location and layout of the proposed BLB2 facility. The proposed BLB2 will operate concurrently with BLB1 and will be located adjacent to BLB1 (see **Figure 3-2**) parallel to privately accessed Fishburn Road and will be of a similar construction to BLB1. BLB2 will be a common-user facility which will handle hazardous and non hazardous bulk liquids and gases similar to BLB1. The BLB2 berth comprises the following main elements:

- a central working platform with a berthing face (including bollards and fenders) and pipe manifold/marine loading arm (MLA) arrangements;
- adjacent berthing dolphins on each side of working platform designed to accommodate up to the maximum design vessel;
- two mooring dolphins on each side of the working platform (four in total). Mooring dolphins will be required on the northern side of the working platform, instead of the existing land based mooring point arrangement used for the BLB1, due to the geometry of the existing shoreline;
- walkways (catwalks) connecting the dolphins and working platform;
- an access bridge structure connecting the working platform with the shore providing for pipeline support and vehicle access;
- support infrastructure including fire control facility/pumphouse and associated tanks, gatehouse and amenities (note that ultimately the need for a gatehouse is dependant on site security arrangement);
- berth fitout, including fire fighting monitors, services such as water, sewer, electrical and communications, amenities and blast proof Operator Shelter.

The BLB2 structure will be owned and maintained by SPC. The pipes, pipe manifolds and MLAs will be owned and maintained by the users.

3.3 Detailed Description of the BLB2 Facility

3.3.1 The BLB2 Working Platform

The working platform is proposed to be a suspended deck structure 76m x 32m in plan (approximately 80% larger than the existing BLB1). It will primarily support the MLAs/manifolds and associated pipework. The working platform will include two ‘integral’ berthing dolphins to resist lateral berthing loads from medium sized ships (large vessels will impact the independent berthing dolphins).

The working platform structure will be made up of the following main elements:

- tubular steel vertical piles (protected against corrosion with high build epoxy paint and/or wrapping system);
- raked tubular steel piles to resist lateral loads (similarly protected against corrosion), including rock anchors to resist uplift loads where necessary;
- precast reinforced concrete caps, beams and slabs;
- in-situ reinforced concrete topping over precast units;
- cone fenders, fence panels and associated chains on berthing face; and
- bollards.

The working platform will support the following:

- MLAs/pipe manifold;
- pipework;
- pedestrian access bridges;
- hose storage;
- personnel hut;
- fire foam water monitors;
- lighting;
- services;
- hose crane/ship access tower (future) and
- spill containment.

3.3.2 Pipelines

The proposed pipelines to be installed as part of the BLB2 project range in sizes depending on the specific pipeline use. Pipelines will range in size, for example, from 80mm (nitrogen lines), 200mm (chemical lines), 250mm (petroleum/bio-diesel lines) and 300mm (LPG lines). Where personnel and vehicles are required to cross pipelines, bridges or culverts will be used.

The pipeline routes, from the wharf to the various users, are shown on **Figures 3-3** & **3-4**. The pipelines will generally be located on the northern side of the BLB2 wharf and access bridge, and along the western side of access road along the shoreline. Pipes will then run parallel to Charlotte Street and into the various user sites in the Port Botany area. All product pipelines will be constructed from welded steel pipe.

3.3.3 Marine Loading Arms & Manifolds

Marine Loading Arms (MLA) are used to transfer the majority flammable and combustible gases and liquids from ships to the transfer pipework and tanks. The arm is a series of pipes connected by sealed swivel joints that permit the end of the arm (i.e. the part that connects to the ship) to move in a three dimensional envelope. The MLAs at the BLB2 will be constructed from 300mm pipework and will be secured to the wharf deck by bolts. The MLA will be fitted with counterweights to facilitate movement of the connection point to the ships manifold, obviating the need for cranes and other handling equipment.

To facilitate liquid transfer, ships will moor adjacent to the MLA such that the operating envelope of the arm connection is within reach of the ship delivery manifold. Once the ship is secured to the wharf, the arm connection will be manoeuvred into place and the connection flange bolted to the ships manifold. New gaskets (spiral wound) will be used for each transfer connection. The MLAs will be installed with a number of safety features as part of the design and operation. These are summarised below.

- Arm is fitted with proximity sensors such that arm movement outside a predefined “envelope” causes alarm, activates an emergency shut down (ESD) and disconnects the arm;
- Connections from MLA to ship are bolted minimising potential for connection failure and release of transfer products;
- Connections are pressure tested to 800kPa (nitrogen) prior to each transfer;
- Transfers are continually monitored for leaks;
- Procedure includes slow pressure and monitoring during start-up;
- An operator is located at the ship’s transfer manifold at all times, the operator is in radio communication with the ship’s control room and wharf operations;
- MLA is monitored and controlled from a central control room (on the shore) with Supervisory Control and Data Acquisition Systems (SCADA);
- An ESD is installed on the wharf (at base of MLA);
- Dry break & weak coupling at MLA connection to the ship; and
- All equipment is classified to AS60079 (Hazardous Area Classification).

When transferring LPG only one MLA will be used, however, for transferring flammable and combustible liquids, up to 4 MLAs may be used simultaneously.

3.3.4 Pedestrian Bridge Over Pipes

Pedestrian access bridges over the pipework will be provided and would include galvanised grill walkway with handrails and a platform over the pipe. The platform would comply with AS1657 (Ref.6).

3.3.5 Spill Containment

Two spill containment areas (bunds) would be located on the deck situated at the:

- Manifold area (an inner bund); and
- The entire working platform (an outer bund).

The manifold area inner bund would include raised kerbing around the product hose manifold area and the MLA/manifold area. This inner bund would contain any accidental minor spills or leaks of petroleum or other chemicals. This bunded area is connected to a collection sump which can then be pumped to a wastewater storage tank. Any liquid (i.e. product or stormwater) that enters this bunded area is deemed to be potentially contaminated and pumped to the storage tank.

The working platform would be provided with a 200mm high continuous vehicle kerbing around the entire deck (this is the outer bund). The access road is to have a trafficable hump, 200mm high, as part of the bund system. As a consequence, all rainwater from the working platform would be collected in a sump which would include a valve outlet to allow drainage to Botany Bay. The valve is normally left open, but closed during ship discharge operations. SPC permission would be required prior to opening the valve after ship discharge operations are completed. If any contamination by product is detected, the stormwater would be diverted to the wastewater storage tank.

Water from the wastewater storage tank would be tested (if required), classified according to the DEC waste management guideline and then disposed of at an appropriate facility.

The closure of the sump discharge valve will be included as part of the pre-transfer checklist.

3.4 Current BLB Users Infrastructure

The current users of BLB1, and who will use the proposed BLB2 and future BLB3, are:

- **Vopak Site A** (chemical terminal) – Vopak A imports a full range of petrochemicals and solvents, lube oils and additives, vegetable oils and tallow. The site currently stores the products in tanks and transfers these from the ship via multiple stainless steel and mild steel product and vapour dock lines running to the BLB1.
- **Vopak Site B** (petroleum terminal) – Vopak B imports gasoline, distillate and jet fuel. The site currently stores the products in tanks and transfers these via 2 x 300mm mild steel dock lines running to the BLB1 and each fitted with a 250mm marine loading arm at the BLB1 wharf.
- **Origin Energy** (LPG terminal) – Origin operates a 6-inch marine loading arm at BLB1.

- **QENOS** (formerly Orica) (propane and butane terminal) **-** Qenos import propane and butane. Facilities exist for the import of ethylene and LPG as well as ethylene exports. Purging facilities are also available. Qenos stores products in tanks and transfers them via pipeline to the BLB1 and a 6 inch marine loading arm at the BLB1 wharf.
- **Elgas Ltd** (LPG facility) – Elgas stores LPG in underground caverns and transfers the product via pipelines to the BLB and a 300mm marine loading arm at BLB1 wharf.
- **Terminals Pty Ltd** (bulk liquid storage) – Terminals provides a bulk liquid storage, handling and repackaging services, and import and export shipping of hazardous and non-hazardous liquid chemicals. In the future Terminals plan to import petroleum products. They currently operate multiple stainless and mild steel dock lines.

The landside terminal and transfer pipeline locations for the above users are shown on **Figure 3-2**.

3.5 Materials Proposed for Transfer at the BLB2 Facility

A range of flammable liquids, liquefied flammable gases and chemicals (including combustibles) are transferred at the BLB. The following range of materials will be transferred:

- Liquefied Petroleum Gas Products – Class 2.1 Flammable Gas;
- Refined Petroleum Products – Class 3 (PG I, II & III) Flammable Liquid;
- BioDiesel – Class C1 (Combustible Liquid);
- Chemical – Class 3 (PGII) Flammable Liquid;
- Chemical – Class 8 (PGII & III) Corrosive Liquids; and
- Chemical – Class 6 (PGII & III) Toxic Liquids.

All products and materials are classified as Dangerous Goods in the Australian Dangerous Goods Code (Ref.4) and the International Maritime Dangerous Goods (IMDG) Code (Ref.5).

3.6 BLB2 Operations

The BLB2 will be constructed with two main liquid transfer mechanisms: marine loading arms and pipelines or pipelines designed for connection of flexible lines. Fuels (flammable liquids and liquefied gases) will be transferred using the marine loading arms whilst chemicals will be transferred using flexible hoses.

3.6.1 Chemical Transfer

Ships will approach the wharf from Botany Bay accompanied by tugs. The ships will be guided into the berth and moored by Ship & BLB crews. Once secured, a detailed and exhaustive procedure is used to establish the transfer operation. The operation is conducted under the requirements of the International Safety Guide for Oil Tankers and Terminals (ISGOTT – Ref.13), which includes a full transfer checklist administered by SPC.

The establishment of the transfer operation includes the connection of the flexible transfer hoses to the ship and wharf. The hoses will be removed from their dedicated storage on the wharf and one end lifted to the ship where it will be bolted to the ship’s manifold. The other end of the hose will be bolted to the shore manifold. Up to 8 flexible hoses can be used simultaneously to transfer chemicals ashore. Once connected the hoses will be pressure tested with nitrogen to 800kPa to ensure hose connection integrity (i.e. no leaks).

Once the pre-operations checklist is complete, which includes the configuration of valves in the transfer line to ensure the chemical is transferred to the correct storage, the pumping operation commences. During this operation there are a number of personnel monitoring the transfer including:

- **Ship Operator -** who remains in the ship manifold area during the full transfer operation. The ship operator is in constant radio contact with the ship's operations centre and control room, where pumping operations are controlled.
- **Shore Operator** – who remains in the shore manifold area during the full transfer operation. The shore operator is in constant radio contact with the shore operations centre and control room where tank filling is controlled.
- **Ship Control Room Operator** – who monitors the ships pumping operations (e.g. flow rates, pressures, tank levels, etc.). The ship control room remains staffed at all times during the transfer operation.
- **Shore Control Room Operator** – who monitors the tank filling and pipeline operations (e.g. pipeline pressures, flow rates, tank levels, etc.). The shore control room remains staffed at all times during the transfer operation.

Each Operating company uses intrinsically safe UHF radios that transmit/receive frequencies unique to that Operating Company. One of these portable radios is temporarily given to the Ship Operator so that communications can be maintained effectively between Ship and Shore.

In addition to the operations control and monitoring personnel detailed above, additional operations staff will monitor the pipeline corridor during the transfer operation.

Once the transfer is complete, the hoses will be purged with nitrogen and the pipeline pigged with nitrogen to remove any remaining liquid from the pipes and hoses. All isolation valves will then be closed. The appropriate ISGOTT checks will then be made and the hoses disconnected and stowed in the dedicated wharf area. The process of purging the hoses whilst still connected to the ship manifold ensures that there is no spillage when the hoses are disconnected and lowered to the wharf deck area.

3.6.2 Flammable Liquids & Liquefied Flammable Gas Transfers

The ship mooring operations will be the same as the chemical transfer operations as detailed in **Section 3.6.1**. Once the ship is moored, and the appropriate checklists (ISGOTT, etc.) have been completed, the MLA can be connected to the ship's manifold. Like the flexible hoses previously described, this is also a bolted connection.

Once the MLA is connected, the system is pressure tested to 800kPa for flammable liquids and 900kPa for LPG to ensure connection integrity. Delivery valves are then configured to transfer the LPG to the required storage and the transfer operations commenced. The transfer operations are monitored throughout the full transfer period by a number of personnel. The monitoring operations will be the same as those described in **Section 3.6.1.**

Once the transfer operations are complete, the MLA and associated vapour return lines to the storage will be purged with nitrogen to remove any liquid/vapour/gas from the lines. All isolation valves will then be closed. The applicable ISGOTT checks will then be made and the MLA disconnected. It is noted that the MLA is fitted with a dry-break coupling at the ship's manifold connection. This will eliminate the potential for spills when disconnecting the MLA from the manifold. Once disconnected, the ship can cast-off from the wharf with the assistance of tugs, and sail as required.

3.7 BLB2 Safeguards

It has been identified that a number of hazards could result in equipment failure and liquid release. Hence, to mitigate this BLB2 will be constructed and operated with a number of hardware (equipment) and software (systems) safeguards, these are summarised below.

To prevent the ship from striking the wharf as it berths, the following safeguards will be used:

- The ship is moored using tugs to minimise the potential for loss of movement control;
- An SPC Pilot is used to bring ship alongside eliminating the chance of unfamiliar berthing;
- Fixed fenders used on the wharf to provide cushioning should excessive impact with wharf occur; and
- Ships have a double hull (liquid not in contact with outer hull) eliminating the potential for leak should the hull be breached.

To minimise the potential for passing ship to strike the moored ship at the BLB or minimise the potential for leak should this occur:

- Ships have a double hull (liquid not in contact with outer hull) eliminating the potential for leak should the hull be breached;
- A marine exclusion zone is in force around the BLB (no unauthorised vessels in the area around the BLB);
- Ships sail at low speed past the BLB, hence, low impact potential should control be lost; and
- Ships passing the BLB would be under tug and pilot control.

The flexible hoses used for chemical transfer are potential leak sources, to mitigate the potential for leak, following safeguards are applied:

- Connections are made using bolted flanges only;

- All hoses are pressure tested annually, minimising potential for hose rupture;
- Hoses are pressure tested with nitrogen prior to each use (800kPa), minimising potential for hose leak during operation;
- New gaskets are used for each transfer, minimising potential for gasket failure;
- Operation of hoses <700kPa, minimising potential for leak considering the test is conducted at 800kPa;
- Start-up procedure to monitor pressuring of hoses including leak detection;
- Operators are in attendance during full transfer cycle;
- Operators in full radio communication with the wharf and shore operations;
- Manual shut down valves located at each end of the flexible hose;
- Operator dedicated to monitoring of all equipment during transfer (leak detection);
- Ships deck has a spill catchment to prevent any release overboard in the event of a spill (i.e. ships scuppers are plugged); and
- Wharf is bunded with a 200mm bund wall all round.

Pipelines are a potential leak source and, hence, to mitigate leaks, the following safeguards are applied:

- Fully welded pipeline along transfer route, minimising flanges and potential leak points;
- The wharf is fully bunded with a bund height of 200mm;
- A containment pit is constructed around the pipe isolation valves (onshore);
- Hydrostatic testing of pipes at commissioning and every 2 years (or when maintenance is performed on pipelines);
- Pipes are maintained empty & liquid free between transfers; and
- Operator monitors operations during transfer (leak monitoring of pipelines).

In the event the ship mooring lines are broken, the ship may move away from the wharf, resulting in rupture of MLA or flexible lines. To minimise this risk the following safeguards are applied:

- Transfer ceases at wind speeds >35kph (hoses isolated);
- Operators (marine) continually monitor the mooring security;
- Wind warning system from Bureau of Meteorology are continually monitored;
- Transfers cease when lightning occurs;
- Predominant winds are “on to the wharf” (ship is blown on to and not off the wharf);
- Securing lines are designed to secure against normal passing ships (i.e. waves generated in the bay); and
- Tug is on 24 hour call in adjacent dock area (Brotherson Dock)

The marine loading arm is a jointed structure with potential leak sources at the rotating arm joints. To mitigate the potential for leaks the following safeguards are applied:

- MLA is hard piped (no flexible connections);
- Arm movement outside established operating "envelope" causes alarms, shuts down (ESD) and disconnects;
- The connection of the MLA to the ship is bolted;
- Connections are pressure tested with nitrogen to 800kPa for liquids and 900kPa for LPG prior to use;
- Joints and connections are continually monitored for leaks by the ship and shore crews;
- The MLA start up procedure includes a staged pressurisation and monitoring to detect any leaks;
- An operator is stationed on board the ship to respond to any incidents and initiate isolation of the transfer in the event of an incident;
- MLA is monitored and controlled from a central control room on shore, with Supervisory Control and Data Acquisition systems (SCADA);
- An ESD is installed at the base of the MLA on wharf;
- A dry break & weak coupling (Emergency Release Coupling) is part of the MLA connection to the ship;
- All equipment is classified to AS60079 to eliminate ignition sources in the wharf area (i.e. Hazardous Area Classification);
- Three fire monitors located on the wharf and can be operated by remote control; and
- A fire water pump fire water pump station is located on the shore (diesel duty/stand-by).

4. HAZARD ANALYSIS

4.1 General Hazard Identification

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

Section 3.5 lists the type of Dangerous Goods (DGs) proposed for transfer and handling at the BLB2 facility. It is noted that all goods listed in this section will be transferred and handled in accordance with ISGOTT and the requirements of the applicable Australian Standard specific to the particular DG listed. **Table 4-1** lists the characteristics of the DGs proposed for transfer and handling at the BLB2 facility.

Table 4-1 Properties of the Dangerous Goods proposed for transfer and handling at the BLB2 facility

Material Name	Class	Hazardous Properties
Liquefied Petroleum Gas – LPG	2.1	Gas is flammable and if released could ignite. Ignited leak at the release source would result in a jet fire. Un-ignited releases could vaporise and causes a gas cloud, which may ignite after a delay and explode. Minimal environmental damage as gas evaporates rapidly with little or no impact to surroundings.
Bio-Diesel (Liquid)	C1	Liquid is combustible and will burn if ignited, resulting in pool fire in the area under the release point. Potential impact to the bio-physical environment depending on spill quantity and containment.
Refined Petroleum Products (Liquids)	3	Liquid is flammable or combustible (C1 & C2) and will burn if ignited, resulting in pool fire in the area under the release point. Potential impact to the bio-physical environment depending on spill quantity and containment.
Corrosive Substance (Liquids)	8	Liquid is corrosive and may damage materials which it contacts causing weakening of structures and equipment. Impact to people could result in chemical burns. Inhalation of vapours could impact mucous membranes. The severity depends upon concentration and duration of impact. Potential impact to the bio-physical environment depending on spill quantity and containment. Note: Chemicals may also have a sub-risk of Class 3 (flammable liquid)
Toxic Substances (Liquids)	6	Liquids are toxic and may impact the bio-physical environment depending on the spill quantity and containment. Impact to people could result in acute or chronic illness and/or dermatological impacts. Vapours may affect mucous membranes and cause breathing impairment. The severity depends upon concentration and duration of impact. Note: Chemicals may also have a sub-risk of Class 3 (flammable liquid)

4.2 Detailed Hazard Identification

4.2.1 Hazard Analysis Workshop

A hazard analysis workshop was conducted to determine the potential hazards, their impact and proposed safeguards at the BLB2 facility. The study was conducted on 26 June 2007 over a three hour period. The following participants attended the study:

Name	Company	Position
Neil Trillo	Vopak Terminals	Safety Manager
Jim Pullin	Sydney Ports Corporation	Manager BLB
Roy Garth	Sydney Ports Corporation	Safety Engineer
Steve Sylvester	Sinclair Knight Merz	Facilitator/Risk Engineer

The hazard identification workshop resulted in the development of a hazard identification table, which is included in the document at **Appendix A**. The study identified a number of potential incidents that could lead to impact to people, plant and the environment. A summary list of hazards is presented below:

- Ship strikes the wharf at excessive speed;
- Moored ship is struck by passing ship;
- Chemical hose failure leading release of chemicals (including flammables/combustibles);
- Chemical pipeline failure leading to release of chemicals;
- Marine loading arm failure leading to flammable gas release;
- Liquefied Flammable Gas (LPG) pipeline failure leading to flammable gas release;
- Marine loading arm failure leading to flammable liquid release;
- Flammable liquid pipeline failure leading to flammable liquid release; and
- Mooring systems failure leading to ship moving away from the wharf and breaking transfer connections.

Each identified hazardous incident has been assessed in detail below.

4.2.2 Ship Strikes the Wharf When Mooring

It was identified that when ships are moored at the BLB, there is a potential for the ship to strike the wharf resulting in hull breach and possible loss of cargo (fuel/gas/chemical) directly to the bay. A review of the mooring procedures identified that ships are brought alongside the BLB under the direction of a SPC Pilot and with the aid of tugs. The ships do not moor at the BLB under their own power or control from the ships Captain. The control of the mooring operation by SPC Personnel and Pilots reduces the potential for errors of unfamiliarity with the mooring operation at the BLB.

By using experienced SPC Pilots and tugs, the ship's speed is minimised and the speed of approach to the wharf carefully controlled. Further, the wharf is fitted with permanent fenders that provide cushioning as the ship touches the wharf. Hence, the potential for impact at speed is negligible.

A review of the designs of ships visiting the BLB indicates that all ships are constructed with double-bottoms, meaning that the tanks storing liquids/gases in the ships do not contact the ships hull (i.e. tank exterior is not in contact with the water). The double-bottom design ensures that there is a space between the storage tank shell and the ship's hull, preventing release of liquid in the event a hull breach occurs.

Based on the procedures for bringing ships alongside at the BLB and the ship design (double bottom), it is concluded that the risk of release as a result of errors in bringing the ship alongside is considered to be negligible, and the risks are assessed to be in the as low as reasonably practicable (ALARP) range. Hence, this incident has not been carried forward for further analysis.

4.2.3 Moored Ship is Struck by Passing Ship

It was identified that ships passing the BLB could move off course, by error, and strikes the moored ship at the BLB. This could result in a hull breach and release of gas/liquid/ chemical. A review of the BLB layout indicates that an exclusion zone has been developed around the BLB whereby vessels are not permitted within the zone. The exclusion zone area is clearly marked on charts and maps of Botany Bay and, hence, any ship approaching the BLB will identify the exclusion zone and remain clear. Large ships moving to and from the Brotherson Dock area (see **Figure 3-1**) will operate under the control of an SPC Pilot, who is well aware of the exclusion zone requirements.

It could be argued that some ships may not be operating using SPC Pilots, charts or maps. This would be valid for smaller vessels that by error could enter the zone and in the worst case strike the moored vessel. However, smaller ships, operating without Pilots, charts or maps, would not be of sufficient size to impact a large tanker (ship) causing hull breach. Further, as noted in **Section 4.2.2**, the ships that unload at the BLB are all constructed with double-bottoms, eliminating the potential for gas/liquid/chemical release in the event of a hull breach.

It is therefore concluded that the risk of a ship striking a moored vessel at the BLB is low and the current safeguards are considered adequate to maintain the risks in the ALARP range.

4.2.4 Chemical Transfer Hose Failure

Chemical Transfers

Once chemical ships are moored, and the appropriate pre-transfer checks are complete, the chemical transfer hose will be connected to the wharf manifold and ship's manifold. Connection will be bolted and a new gasket will be used for each transfer. Once connected, the transfer hose will be tested with nitrogen to 800kPa and the joints and hose examined for leaks. Once the hose integrity is proven, transfer will commence, under monitoring from wharf and ship operators, at low pressure, gradually rising to a maximum transfer pressure of 700kPa.

Although the operating pressure is below the test pressure, there is a potential for hose rupture or leak during the transfer, releasing hose contents to the environment. In the event a hose rupture occurs in the ship's deck area, spills will be retained on the deck of the ship, preventing release to the bay, as the ship's scuppers will be plugged during the transfer. In the event the rupture leak occurs in the wharf area, the wharf bund will contain leaks and prevent release to the bay. However, if the rupture or leak occurs in the section between the ship and wharf, then the chemical could be released directly to the bay, resulting in potential environmental impact to the area where the chemical spill occurs. Due to the height of the ships side, a rupture could result in the hose "whipping" and spraying chemicals beyond the ships deck or wharf deck bund, however, the flexible hoses are constructed with an internal steel spiral and are bound externally with rope. Hence, hose rupture may result in a split, but a complete severing of the hose in not considered feasible due to the hose design.

It is noted that some chemicals transferred by flexible hose are toxic. However, a review of the toxic materials transferred via hose (during the PHA) identified that all materials transferred, containing a toxic content, are liquids only and transferred at ambient temperature. The liquids do not vaporise readily as they are transferred at temperatures well below flash point. There are no toxic liquefied gases transferred by hose. Any minor vaporisation around the surface of the spill would not generate a toxic vapour cloud as the materials are all transferred well below flash point temperatures. The release rates from pools of toxic materials spill would be too low to enter into models (i.e. there would be no impact downwind from such releases).

As there is a potential for failure of the flexible transfer hose (i.e. rupture or leak) resulting in chemical release directly to the bay, this incident has been carried forward for frequency analysis, noting that there is an immediate consequence as a result of the release (e.g. environmental damage from chemical impact to Botany Bay).

Flammable-Combustible Liquid Transfer

The liquid transfer by flexible hose will also include transfer of flammable and combustible (C1/C2) liquids. Release incidents could occur in a similar manner to those described above for chemicals. However, unlike chemicals, a spill could be ignited resulting in a fire.

Flammable & combustible liquids will be transferred using a 150mm flexible hose with a maximum transfer rate of 200m3/hour or 50 Litres/second (L/s). Hence, in the event of a catastrophic hose failure, the maximum flow rate from the hose is 50L/s.

In the event a release of flammable/combustible liquid occurs, the release will pool on the wharf deck. Ignition of the pool would result in a pool fire that could radiate heat beyond the wharf area, impacting the risk at the existing contour. This incident has therefore been carried forward for consequence analysis.

4.2.5 Chemical Pipeline Failure

The chemicals will be transferred from the ship to the selected shore tank via pipelines. Pipelines will be fully welded along their length, eliminating the potential for release at joints, flanges, etc. Flanges and valves at the wharf manifold are contained within the manifold bund and wharf deck bunded areas. Hence, in the unlikely event of a release in this area, the spill will be contained within the bunds and there will be no spill to the environment.

A pipe line isolation valve station will be located at the shoreline and will be constructed with a containment pit to prevent release to the environment in the unlikely event of leaks from flanges and valves. It is understood that the valve containment pit will be fitted with a drain valve that will normally be open, permitting rainwater to be released during non-transfer operations. During this period, there will be no potential for release of chemicals from the pipeline as all pipelines will be purged after transfer ensuring pipelines rest empty between transfers. Prior to transfers commencing, the isolation valve pit drain valve will be closed to ensure any spill are contained. However, should a larger spill occur between manual inspection periods, there is a potential for the pit to fill and release chemicals to the environment. Hence, **it is recommended that consideration be give to installing a level alarm switch at the isolation valve pit to detect any leaks and alarm at the transfer control room.**

Based on the above analysis and the assumption that a level switch will be installed on the isolation valve pit, it is considered that the risk of chemical release to the environment from pipelines and vales is low and within the ALARP range. Hence, this incident has not been carried forward based on the assumption that the recommendation is implemented.

4.2.6 Marine Loading Arm Failure (Flammable Gas)

Un-odorised liquefied flammable gases will be transferred from the ship to the Elgas, Qenos and Origin Energy storage facilities using a marine loading arm (MLA). Once the pre-transfer checks have been completed, the MLA will be connected to the ship's manifold via a bolted connection, using a new spiral wound gasket for each transfer connection. Once connected to the ship, the MLA system is pressure tested to 900kPa and the connection, MLA swivel joints, valves, etc., examined for leaks. A Vapour Return hose is connected to the Ship's Vapour Return line and to the wharf pipeline Vapour Return. Once the MLA integrity is proven, transfer will commence, under monitoring from wharf and ship operators. The operation will commence at low pressure, gradually rising to a maximum transfer pressure of 850kPa.

Although the operating pressure of the system (850kPa) is below the transfer test pressure (900kPa), there is a potential for minor leaks to develop at gaskets, MLA swivel joints and valves. A release of gas would be detected by operators who continually monitor the transfer operation (both ship and wharf sides). Once detected, the transfer would be isolated at the ship by stopping the ship's discharge pump and at the wharf by an isolation valve at the base of the MLA.

In addition to the manual leak detection, provided by continual operator monitoring, a gas detection system will be installed at the wharf. This system will be linked to the Elgas control room, which is staffed 24 hours per day, 7 days per week. For BLB2 the gas detectors will be established to initiate an alarm at 20% LEL. Operators will immediately shut down transfer operations in this event and conduct the appropriate investigation.

However, if not detected minor leaks may grow into larger leaks, which could lead to the release of larger quantities of gas forming a gas cloud that could ignite resulting in a flash fire or gas cloud explosion. This could have consequence impacts beyond the confines of the BLB area and could result in the increase of the existing Port Botany Land Use Safety Study risk contours. Hence, this incident has been carried forward for further analysis (Consequence, frequency and risk).

4.2.7 LPG Pipeline Failure

The LPG will be transferred from the ship to the selected storage vessels via pipelines. Pipelines will be fully welded along their length, eliminating the potential for release at joints, flanges, etc. Flanges and valves at the wharf manifold have been minimised to maintain a low potential release profile and joints will be made using spiral wound gaskets, eliminating the potential for gasket blowout. Hence, major releases from flanges are eliminated.

A pipe line isolation valve station will be located at the shoreline and liquid isolation valves will be will be constructed with a containment pit to prevent release to the environment in the unlikely event of leaks from flanges and valves. However, gas systems should not be located near to or over pits, as releases could fill the pit with gas and, if ignited, result in explosion. Hence, **it is recommended that the gas isolation valves at the shoreline be separated from the other isolation valves (i.e. flammable liquids and chemicals) to eliminate the potential for any leaks to accumulate in the pit.**

Notwithstanding the above discussion, failure to detect minor leaks at valves and flanges could result in the leaks growing, leading to larger gas releases. This could lead to the potential for the formation of a gas cloud that if ignited, could cause a flash fire or gas cloud explosion. This could have consequence impacts beyond the confines of the BLB area and could result in the increase of the existing Port Botany Land Use Safety Study risk contours (Ref.1). Hence, this incident has been carried forward for further analysis (Consequence, frequency and risk).

4.2.8 Marine Loading Arm Failure (Flammable/Combustible Liquid)

Once the flammable/combustible liquid ships are moored, and the appropriate pre-transfer checks are complete the flammable/combustible liquid MLA will be connected to the ship's manifold via a bolted connection, using a new gasket for each transfer connection. Once connected to the ship, the MLA system is pressure tested to 800kPa and the connection, MLA swivel joints, valves, etc., examined for leaks. Once the MLA integrity is proven, transfer will commence, under monitoring from wharf and ship operators. The operation will commence at low pressure, gradually rising to a maximum transfer pressure of 700kPa.

Although the operating pressure of the system (700kPa) is below the transfer test pressure (800kPa), there is a potential for minor leaks to develop at gaskets, MLA swivel joints and valves. A release of flammable/combustible liquid would be detected by operators who continually monitor the transfer operation (both ship and wharf sides). Once detected, the transfer would be isolated at the ship, by a manifold isolation valve, and at the wharf by an isolation valve at the base of the MLA. Leaks and spills from the equipment could reach the environment, however, spills will be retained on the deck of the ship, preventing release to the bay, as the ship's scuppers will be plugged during the transfer. In the event the rupture leak occurs in the wharf area, the wharf bund will contain leaks and prevent release to the bay. It is noted that the section of MLA that stretched over the water (i.e. the space between the ship and wharf, is a solid pipeline and failures in this section are considered to be negligible. Hence, based on the proposed protection systems, the risk of flammable/combustible liquid release to the environment is low and within the ALARP range.

Notwithstanding the low assessed risk of impact to the environment, in the event a release occurs, a pool of flammable liquid will form under the spill area. In the unlikely event of spill ignition, a pool fire would occur, radiating heat to the surrounding areas. In this unlikely event, the impacts may occur beyond the BLB2 area resulting in a potential increase of the existing Port Botany Land Use Safety Study risk contours. Hence, this incident has been carried forward for further analysis (Consequence, frequency and risk).

4.2.9 Flammable/Combustible Liquid Pipeline Failure

The flammable/combustible liquids will be transferred from the ship to the selected shore tank via pipelines. Pipelines will be fully welded along their length, eliminating the potential for release at joints, flanges, etc. Flanges and valves at the wharf manifold are contained within the manifold bund and wharf deck bunded areas. Hence, in the unlikely event of a release in this area, the spill will be contained within the bunds and there will be no spill to the environment.

A pipe line isolation valve station will be located at the shoreline and will be constructed with a containment pit to prevent release to the environment in the unlikely event of leaks from flanges and valves. It is understood that the valve containment pit will be fitted with a drain valve that will normally be open, permitting rainwater to be released during non-transfer operations. During this period, there will be no potential for release of flammable/combustible liquids from the pipeline as all pipelines will be purged after transfer ensuring pipelines rest empty between transfers. Prior to transfers commencing, the isolation valve pit drain valve will be closed to ensure any spill are contained. However, should a larger spill occur between manual inspection periods, there is a potential for the pit to fill and release flammable/combustible liquids to the environment. Hence, **it is recommended that consideration be give to installing a level alarm switch at the isolation valve pit to detect any leaks and alarm at the transfer control room.**

Notwithstanding the environmental protection systems discussed above, in the event a release occurs, a pool of flammable liquid will form under the spill area (pit). In the unlikely event of spill ignition, a pool fire would occur, radiating heat to the surrounding areas. In this unlikely event, the impacts may occur beyond the BLB2 area resulting in a potential increase of the existing Port Botany Land Use Safety Study risk contours (Ref.1). Hence, this incident has been carried forward for further analysis (Consequence, frequency and risk).

4.2.10 Mooring Systems Fail

It was identified that in the event the mooring lines failed, there is a potential for the ship to move away from the wharf. If a flexible hose or MLA was connected, the transfer system could be broken, resulting in a line rupture and gas/flammable-combustible liquid/chemical release.

A review of the MLA design identified that this system is fitted with an Emergency Release Coupling (ERC) that is a Weak-Link at the ship to arm connection point. This ERC link is fitted with a dry break coupling that will automatically isolate in the event the link is broken. Hence, should the ship move away from the wharf, and the MLA be breached, the dry break coupling will activate and prevent release of material to the environment. In addition, the MLA is fitted with proximity sensors at the swivel joints. These sensors monitor the MLA position and in the event arm moves outside a predetermined operating envelope (i.e. the ship moves too far forward/aft or away from the wharf), the emergency shut down valves at the wharf and ship will be isolated. In addition to the automatic protection systems, ship and shore operators will be present during the full transfer operation. Hence, at the first sign of potential mooring security integrity failure, all transfers will be isolated, eliminating the potential for release of material to the environment. Hence, for the MLA transfer, movement of the ship and potential extension of the MLA will not result in a release to the environment. This incident has, therefore, not been carried forward for further analysis.

A review of the flexible transfer hose operations, for chemical transfers, identified that the chemical hoses are connected to the ship via bolted connections. In the event the ship's moorings fail, and the ship moves forward/aft or away from the wharf, there is a potential that the hoses could be stretched eventually rupturing. A review of the hose design identified that there was no weak link coupling planned for this installation. However, a number of operational safety features are planned for the BLB2 operation, these include:

- Review of operations at wind speeds >35knots. Wind warning systems have been established with the Bureau of Meteorology for BLB1 and will be incorporated into the BLB2 operations. BLB Management will review wind/weather conditions to determine whether operations should cease, based on the wind direction and potential for mooring failure. In these cases, additional mooring lines can be deployed, hoses isolated to prevent any release should the moorings fail under high wind loads or hoses purged of product and disconnected;
- Operators (marine) continually monitor the mooring security. In the event mooring security integrity becomes compromised, transfer operations will cease until the mooring security has been re-instated. This will prevent any potential release to the environment;
- In the event of lightning, there is a potential for a lighting strike that could impact the moorings or transfer equipment resulting in chemical release. However, where lighting is imminent, all transfer operations will cease until the electrical storm has passed;

- Securing lines have been designed to withstand normal loadings for waves generated by passing ships and refracted waves entering Botany Bay from the Pacific Ocean. Hence, potential for un-warned failure of these lines is low; and

- Tug is on 24 hour call in adjacent dock area (Brotherson Dock).

A review of the wind rose for the Botany Bay area identified that the predominant wind is from the south east, blowing onto the wharf and minimising the risk of the ships moorings being under wind load from the ship being blown off the wharf. In addition to all of the above safeguards (hardware, software and inherent), a tug, located in the adjacent Brotherson Dock, is on call 24 hours per day. Hence, in the event of an imminent failure of the moorings, a tug could be called to stabilise the ship and prevent it from moving away from the wharf.

Based on the above safeguards, the risk of failure of the moorings and subsequent chemical transfer line failure is considered to be low and within the ALARP range. Hence, this incident has not been carried forward for further analysis.

4.2.11 Application of Fire Water – Containment of Contaminated Fire Water

In the event of an incident at the BLB2 facility, it will be necessary to initiate a response. A spill of chemicals may occur as a result of chemical hose or transfer system incidents. However, these would be retained by the proposed containment systems at the BLB2 (e.g. wharf bunding). However, in the event of a gas release or flammable/combustible liquid release, it will be necessary to apply fire water to mitigate the incident.

In the event of an ignited gas leak, a gas jet fire would occur. This could radiate heat to the surrounding areas and there will be a need to cool these areas with fire water. Fire water monitors have been installed on the wharf and these will be used to cool the jet fire impacted areas. As the fire burns flammable gas, the fuel source is fully consumed in the fire and the cooling fire water does not absorb any contaminants. Hence, a release of fire water from a gas jet fire will not result in contamination of the fire water or the environment.

However, in the event of a flammable/combustible liquid fire, there is a potential for the contaminants to pool. Applied fire water could become contaminated with these products and, if the fire water escapes from the bunded wharf deck, these contaminants could be carried to the bay. In this event, the contaminants (flammable/combustible liquids) generally have a lower specific gravity than water and, hence, they would float on top of the bay. SPC has emergency procedures for the deployment of marine booms, which can be quickly deployed to contain marine pollutants. The booms will contain any flammable/combustible liquid contaminants that are carried into the bay by fire water. Contained liquids will then be “swept” to a collection point and transferred to tankers for disposal at a registered waste disposal facility.

The deployment of booms is contained within a marine spill response emergency plan and procedure. This plan and procedure is regularly tested by desk top and actual drills/exercises conducted with SPC and combat agency personnel.

Based on the above safeguards, the risk of impact to the bay and surrounds is considered low and within the ALARP range. Hence, this incident has not been carried forward for further analysis.

5. CONSEQUENCE ANALYSIS

5.1 Consequence Impact Criteria

To determine whether the proposed BLB2 will impact the existing Port Botany Land Use Study risk criteria (Ref.1), it will be necessary to determine the consequence impacts, from the postulated incidents at the BLB2 facility, at the risk contour distances detailed in the Port Botany Study (Ref.1).

A review of the Port Botany Land Use Study risk criteria indicates that there are two contours plotted for risk; 1x10-6 chances per year (or 1 chance per million per year (pmpy)) and 50pmpy. The former risk applies to residential areas, the latter to industrial sites. Hence, as the fatality risk has been used in the development of contours, incidents at the BLB2 must result in fatality for these to impact the existing risk contours. Where an incident does not result in fatality, at the impact distance from the incident to the contour, then there is no risk of the incident impacting the contour, and no further analysis is required.

The following consequence criteria will be used in the assessment:

- **Heat Radiation Impact** – levels below 4.7kW/m^2 not considered to result in fatality (Ref.9);
- **Explosion Overpressure** – levels below 7kPa not considered to result in fatality (Ref.9);
- **Flash Fire** – fatality occurs to people inside the flash fire, no fatalities where people are beyond the LEL;

Each incident assessed in this section has been reviewed against these criteria.

5.2 Distances from the BLB2 Facility to the Port Botany Study Criteria

A review of the Port Botany Land Use Safety Study was conducted to determine the impact distance from the BLB2 for each of the fatality risk criteria. The existing BLB wharf was used as a basis for the scaling to determine the contour impact distances. The distance from the wharf to the 50 pmpy contour is 50m (circular). The distance from the wharf to the 1pmpy contour is 80m (west).

5.3 Incidents Carried Forward for Consequence Analysis

The following incidents were identified in the hazard analysis (**Section 4**) to have a potential to increase the existing risk profile for the Port Botany area, as detailed in the Port Botany Land Use Safety Study (Ref.1):

- LPG Transfer MLA Failure – leak/release, ignition and explosion/fire;
- Flammable/Combustible Liquid transfer hose failure –leak/release, ignition and fire;
- LPG Pipeline Failure – leak/release, ignition and explosion/fire;
- Flammable/Combustible Liquid MLA Failure – leak/release, ignition and fire; and
- Flammable/Combustible Liquid Pipeline Failure - leak/release, ignition and fire.

A detailed consequence analysis has been conducted in **Appendix B**. Incident consequence summaries are presented in the following sections.

5.4 LPG Transfer - MLA Failure

Incidents at the MLA transfer point can occur as a result of a number of scenarios. The scenarios selected for this study were the following:

- Leak of LPG at the ships manifold connection due to a failed flange connection;
- Leak of LPG due to a catastrophic failure of the MLA at a swivel joint;
- Leak of LPG at a pipeline flange; and
- Leak of LPG at a valve stem.

The consequences of each incident are summarised in the sections below. The detailed analysis of the ship's manifold incidents is developed in **Section B3** of **Appendix B**.

5.4.1 LPG Incident at the Ships Manifold and MLA

In the event of a gasket failure at the ship's manifold (i.e. where the MLA connects to the ship) or at the MLA (i.e. flanges in the MLA system) a gas release could be immediately ignited or ignited after a delay. In the event of an immediate ignition, a jet fire would result. If a delayed ignition occurred a flash fire or gas cloud explosion could occur.

The analysis in **Appendix B** identified the impact distances for each of these incidents. The results are summarised below.

Jet Fire - Heat Radiation Impact

As a results of a flange leak and immediate ignition, the distances to the selected heat radiation impacts from a ship's manifold or MLA flange jet fire are:

- 4.7kW/m^2 = 10m.
- 12.5kW/m2 = 6m
- 23kW/m^2 = 4m

Based on the above values, there is no potential for fatality beyond 10m. This is within the existing 50pmpy contour, hence, this incident will not impact the existing risk contours. This incident has not been assessed further in the study.

Flash Fire

As a result of a flange leak, gas cloud formation, ignition and flash fire, the maximum distance of an LPG gas cloud from the ships manifold flange or MLA flange release is 20m, based on F1.5 wind weather conditions (worst case incident dispersion). This is within the existing 50pmpy contour, hence, this incident will not impact the existing risk contours. This incident has **not** been assessed further in the study.

SKM

Explosion

As a result of a flange leak, gas cloud formation, ignition and explosion, the distance from the ship's manifold or MLA flange to an explosion overpressure of 7kPa is 62m. This exceeds the 50pmpy contour distance of 50m (scaled from the Botany Land Use Safety Study, Ref.1) and therefore this incident has been carried forward for frequency and risk assessment.

5.4.2 Catastrophic LPG Incident at the MLA

In the event of a catastrophic failure of the LPG MLA (i.e. rupture of a swivel joint), then the following impacts would occur.

Jet Fire - Heat Radiation Impact

As a result of a catastrophic failure of the LPG MLA, immediate ignition and jet fire, the distances to selected heat radiation impacts from a fire are:

- 4.7kW/m^2 = 160m.
- 12.5kW/m2 = 120m
- 23kW/m^2 = 80m

Based on the above values, there is a potential for fatality up to 160m from the MLA. This exceeds the distance to the existing 50pmpy contour, hence, this incident has been carried forward for further assessment in the study.

Flash Fire

As a result of a catastrophic failure of the LGP MLA, gas cloud development, ignition and flash fire, the maximum distance of an LPG gas cloud from the LPG MLA is 195m, based on a continued release for 60 seconds (i.e. before the emergency valves close) and an E2 wind weather conditions (worst case dispersion incident). Hence, the flash fire will impact up to 195m. This exceeds the distance to the existing 50pmpy contour of 50m; hence, this incident has been carried forward for further assessment in the study.

Explosion

As a result of a catastrophic failure of the LPG MLA, gas cloud development, ignition and explosion, the distance from the MLA to an explosion overpressure of 7kPa is 160m. This exceeds the 50pmpy contour distance of 50m and, therefore, this incident has been carried forward for further assessment in the study.

5.4.3 LPG Incident at the Transfer Pipework

Incidents at the LPG transfer pipework include flange and valve leaks. These may occur at the isolating valve station only, as the remaining pipework is fully welded. In the event of a leak from a flange or valve, the following consequences would result.

Jet Fire - Heat Radiation Impact from Flange Leak

As a result of a leak at a valve flange in the pipeline isolating valve station (i.e. any gas flange in the valve station), immediate ignition and jet fire, the distances to selected heat radiation impacts are:

- 4.7kW/m^2 = 10m.
- 12.5kW/m2 = 6m
- 23kW/m^2 = 4m

The pipework isolation valve station is located outside the existing 50pmpy contour, and is within 20m of the adjacent property. Whilst there will be no impact at the adjacent property as a result of this postulated incident (i.e. fatalities may occur only up to 10m from the valve station), there is a potential that the 50pmpy contour could be extended onto the shore line as a result of this incident. Hence, this incident has been carried forward for frequency and risk assessment.

Jet Fire - Heat Radiation Impact from Valve Leak

As a result of a valve stem leak at the pipeline isolating valve station (i.e. any LPG valve in the valve station), immediate ignition and jet fire, the distances to the selected heat radiation impacts from a jet fire are:

- 4.7kW/m^2 = 18m.
- 12.5kW/m2 = 10m
- 23kW/m^2 = 7m

The pipework isolation valve station is located outside the existing 50pmpy contour, and is within 20m of the adjacent property. Whilst there will be no impact at the adjacent property as a result of this postulated incident (i.e. fatalities may occur only up to 10m from the valve station), there is a potential that the 50pmpy contour could be extended onto the shore line as a result of this incident. Hence, this incident has been carried forward for frequency and risk assessment.

Flash Fire

As a result of a valve/flange leak at the pipeline isolating valve station (i.e. any flange/valve in the valve station), delayed ignition and flash fire, the maximum distance of an LPG gas cloud to LEL from the pipeline valve/flange leak incident is 44m, based on F1.5 wind weather conditions. There is a potential that a fatality could occur at the adjacent property to the east (Elgas gas storage facility) and that the 50pmpy contour could be extended, onto the shore line (i.e. location of the pipeline isolation valve station). Hence, this incident has been carried forward for frequency and risk assessment.

Explosion

As a result of a valve/flange leak at the pipeline isolating valve station (i.e. any flange/valve in the valve station), delayed ignition and explosion, the distance from the pipeline isolating valve station to an explosion overpressure of 7kPa is 62m, based on a valve/flange leak incident. There is a potential that a fatality could occur at the adjacent property to the east (Elgas gas storage facility) and that the 50pmpy contour could be extended, slightly, onto the shore line. Hence, this incident has been carried forward for frequency and risk assessment.

5.5 Flammable/Combustible Liquids – Ship Connection Failure

Pool Fire - Heat Radiation Impact from Ship's Connection Flange Leak

As a result of a flammable/combustible liquid leak at the ships connection flange, immediate ignition and pool fire, the distances to the selected heat radiation impacts are:

- $4.7kW/m^2$ = 40m
- 12.5kW/m2 = 29m
- $23kW/m^2$ = 22m

Based on the above values, there is no potential for fatality beyond 40m. This is within the existing 50pmpy contour, hence, this incident will **not** impact the existing risk contours. This incident has **not** been assessed further in the study.

5.6 Flammable/Combustible Liquids – Flexible Hose Failure

As a result of a flammable/combustible liquids transfer hose failure (rupture), immediate ignition and pool fire, the distances to the selected heat radiation impacts are:

- $4.7kW/m^2$ = 70m.
- $12.5kW/m^2$ = 50m
- $23kW/m^2$ = 33m

Based on the above values, there is a potential for fatality up to 65m from the fire. This is beyond the existing 50pmpy contour, which is only 50m from the fire (heat radiation = 10kW/m2 at this contour), hence, this incident may impact the existing risk contours and, therefore, has been carried forward for further analysis in the study.

5.7 Flammable/Combustible Liquids – MLA Failure

Pool Fire - Heat Radiation Impact from MLA Catastrophic Failure

As a result of an MLA catastrophic failure, flammable liquid release, immediate ignition and pool fire on the wharf, the distances to selected heat radiation impacts are:

- $4.7kW/m^2$ = 68m.
- $12.5kW/m^2$ = 39m
- $23kW/m^2$ = 24m

Based on the above values, there is a potential for fatality up to 68m from the MLA. As the distance from the BLB2 wharf to the existing 50pmpy contour is 50m, there is a potential for fatality to occur at the contour location, hence, this incident has been carried forward for further assessment in the study.

5.8 Flammable/Combustible Liquids – Pipeline Failure

As discussed in the hazard analysis section, the pipelines will be fully welded along their lengths, with flanges and valves being located at the point where the pipelines meet the wharf. At this location, a valve station will be installed to provide isolation of the pipelines from the wharf. The analysis conducted in **Appendix B** identified that leaks from valves and/or flanges would be retained in the bunded valve pit. Hence, the magnitude of fires in this area is governed by the size of the valve pit and not by the magnitude of releases from the valves/flanges. The heat radiation analysis below, for the flange/valve releases, results in the same magnitude of impact.

5.8.1 Pipeline Flange Leak – Pipeline Isolation Valve Station

As a result of a valve station flange leak, immediate ignition and pool fire, the distances to selected heat radiation impacts are:

- 4.7kW/m^2 = 33m.
- 12.5kW/m^2 = 24m
- 23kW/m^2 = 18m

The pipework isolation valve station is located on the shore line and outside the existing 50pmpy contour, hence, as fatalities may occur up to 33m from the valve station (valve leak), there is a potential that the 50pmpy contour could be extended, onto the shore line itself. Further, there is also a potential that the fatality risk impacts could exceed the published risk criteria (Ref.9) at the closest adjacent facility to the east (Elgas gas storage facility). Hence, this incident has been carried forward for frequency and risk assessment.

5.8.2 Pipeline Valve Leak – Pipeline Isolation Valve Station

As a result of a valve leak (at the valve pipeline station) immediate ignition and pool fire, the distances to selected heat radiation impacts are:

- 4.7kW/m^2 = 33m.
- 12.5kW/m^2 = 24m
- 23kW/m^2 = 18m

The pipework isolation valve station is located outside the existing 50pmpy contour, hence, as fatalities may occur up to 33m from the valve station (valve leak), there is a potential that the 50pmpy contour could be extended onto the shore line. In addition, there is also a potential that the fatality risk impacts could exceed the published risk criteria (Ref.9) at the closest adjacent facility to the east (Elgas gas storage facility). Hence, this incident has been carried forward for frequency and risk assessment.

5.9 Summary of Incidents Carried Forward for Further Analysis

From the analysis conducted above, for each of the postulated hazardous incidents, the following list of incidents has been carried forward for further analysis:

- Flange Leak at the Ship's manifold connection (LPG) resulting in explosion;
- MLA catastrophic failure (LPG) resulting in jet fire;
- MLA catastrophic failure (LPG) resulting in flash fire;

- MLA catastrophic failure (LPG) resulting in explosion;
- Flexible hose rupture (flammable/combustible liquids) resulting in fire;
- Flange leak at the isolating valve station (LPG) resulting in jet fire;
- Valve leak at the isolating valve station (LPG) resulting in jet fire;
- Flange/Valve at the isolating valve station (LPG) resulting in flash fire;
- Flange/valve leak isolating valve station (LPG) resulting in explosion;
- MLA catastrophic failure (Flam/Comb Liquid) resulting in pool fire on the wharf; and
- Flange/ valve leak isolation Valve station (Flam/Comb Liquid) resulting in pool fire.

Based on the initial criteria against which these incidents were selected (**Section 5.1**), the flash fire incidents are all assumed to result in fatality. Hence, the probability of fatality as a result of these incidents is 1. However, explosion overpressure and heat radiation impacts may not necessarily result in fatality. The probability of fatality from these incident impacts is a function of the heat radiation intensity and exposure time, and for explosion overpressure the magnitude of the pressure wave. Therefore, it is necessary to assess the probability of fatality to determine whether the incident has the propensity to impact the existing risk contours of adjacent sites.

5.10 Fatality Probability

In order to determine whether there is a fatality probability at the distance to the selected heat radiation contours from each of the incidents, a probit analysis has been conducted. Probit analysis is a relationship between an incident consequence and the probability of fatality based on incident exposure time and impact severity.

The probit equation takes the form:

$$Y = k_1 + k_2 \ln (C^n t) \qquad \text{- (Ref.10)}$$

Where: k_1 = constant;
k_2 = constant;
n = constant
C = exposure concentration; and
t = exposure time (s)

The constants k1, k2 and n are values related to the specific event, the exposure concentration, C, may be toxic gas, heat radiation or explosion overpressure exposure. The time (t), may be based on a number of factors such as time to evacuate, time for the emergency response personnel to fight the fire, time for operators to isolate systems within the impact zone, etc.

Once the probit value has been estimated, it is compared to the probit curve (shown at **Figure 5-1**). The probability of fatality may then be read from the curve.

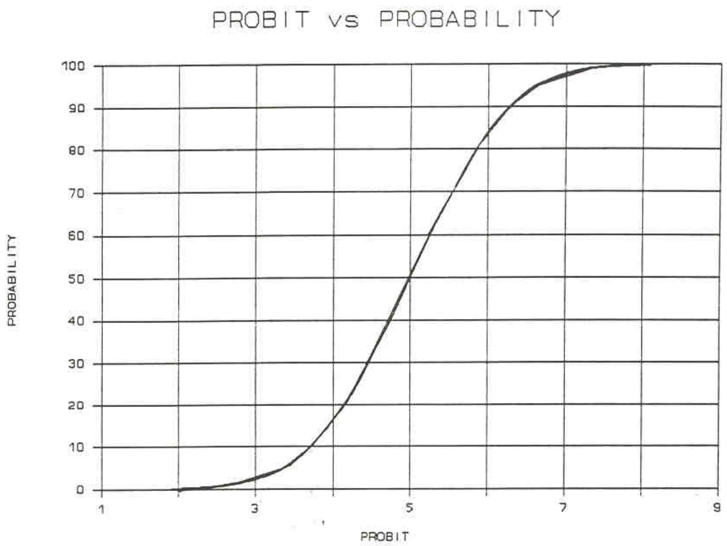

Figure 5-1 Probit vs Probability Curve (Ref.10)

The probit has therefore been applied to each of the events detailed in this section to determine the probability of fatality at the points of interest.

An example of the probit application has been applied to an explosion as a result of an LPG leak from the ship's manifold connection. The Cirrus model (Ref.7) was reviewed and the overpressure impact at 50m from the explosion centre (i.e. the location of the 50pmpy contour) is 9.3kPa.

The probit equation for explosion is:

$Y = k_1 + k_2 \ln (P_s)$ ------- (Ref.10)

Where: $k_1 = -77.1$;
$k_2 = 6.91$;
Ps = Static Overpressure (Pa)

$Y = -77.1 + 6.91 \ln (9300) = -13.95$.

Applying -13.95 to **Figure 5-1** results in a 0 (zero) fatality probability. Hence, this incident will not impact the contours and no further analysis is required for this scenario.

An example of the probit application has been applied to fire as a result of a flammable liquid leak from a ruptured flexible hose. The Cirrus model (Ref.7) was reviewed and the heat radiation impact at 50m from the fire (i.e. the location of the 50pmpy contour) is 10kW/m2.

The probit equation for fire is:

$Y = k_1 + k_2 \ln (I^{4/3} t)$ ------- (Ref.10)

Where: k_1 = -36.4.1;
k_2 = 2.56;
I = Heat Radiation Intensity (kW/m^2)
t = 60 seconds

Y = -36.4 + 2.56 ln (104/3 x 60) = -18.1

Applying -18.1 to **Figure 5-1** results in a 0 (zero) fatality probability. Hence, this incident will not impact the contours and no further analysis is required for this scenario.

Table 5-1 has been developed to summarise the application of probit to each of the events to determine whether further analysis is required. It is noted that the flash fire incidents have not been included in this assessment as the probability of fatality in a flash fire (where people are caught within the gas cloud envelope) is 1. These incidents (flash fires) have been carried forward directly to **Section 7** for risk assessment.

Table 5-1 Summary of Probit Analysis applied to incidents at the BLB2 facility

Incident	k_1	k_2	n	I/P_s	t	Y	P_f	Remarks
Explosion – Ship's manifold connection (LPG)	-77.1	6.91	-	9,300kPa	-	-13.95	0	Not carried forward for further analysis
Jet fire – MLA catastrophic failure (LPG)	-36.4	2.56	4/3	23kW/m^2	180s	11.9	1	Incident carried forward for further analysis
Explosion – MLA catastrophic failure (LPG)	-77.1	6.91	-	27,900kPa	-	-6.4	0	Not carried forward for further analysis
Flexible hose rupture (flammable/ combustible liquids –pool fire (wharf)	-36.4	2.56	4/3	12.5kW/m^2	60	-17.3	0	Not carried forward for further analysis
Jet Fire – Flange leak isolating valve station (LPG)	-36.4	2.56	4/3	23kW/m^2	30s	4.6	0.35	Incident carried forward for further analysis
Jet Fire – Valve leak Isolating valve station (LPG)	-36.4	2.56	4/3	23kW/m^2	30s	4.6	0.35	Incident carried forward for further analysis
Explosion – Flange/valve leak isolating valve station (LPG)	-77.1	6.91	-	53,500kPa (at the road)	-	-1.86	0	Not carried forward for further analysis
Pool Fire – MLA catastrophic failure (Flam/Comb Liquid)	-36.4	2.56	4/3	8kW/m^2	30	-20.6	0	Not carried forward for further analysis
Pool Fire – Flange/ valve leak isolation Valve station (Flam/Comb Liquid)	-36.4	2.56	4/3	25kW/m^2 (at the road)	30	4.88	0.48	Incident carried forward for further analysis

5.11 Impacts at BLB1

The closest facility to the BLB2 wharf is the BLB1 wharf. Hence, incidents occurring at the BLB2 wharf may impact the BLB1 wharf at levels exceeding the acceptable impact or risk criteria. A review of the incidents assessed above indicates that only two incidents have the potential to impact the BLB1, these are listed below along with the impact distances.

Jet fire as a result of a catastrophic MLA failure - Heat Radiation Impact Distances:

- $4.7kW/m^2$ = 160m }
- 12.5kW/m2 = 120m } see **Appendix B**, **Section B4.2**
- $23kW/m^2$ = 80m }

Explosion as a result of a catastrophic MLA failure - Heat Radiation Impact Distances:

- 0.15 barg = 90m }
- 0.07 barg = 160m } see **Appendix B**, **Section B4.4**

A review of the selected impact criteria (**Section 5.1**) indicates that the distance to the maximum impact criteria, from BLB2 is 160m for heat radiation and 160m for explosion overpressure.

Figure 5-2 shows the separation distance between the BLB1 & BLB2 wharf/ships. It can be seen that the distance from the area where incidents may occur at BLB2 (i.e. the wharf deck/ship's manifold) is over 200m from the adjacent ship's bow. As the impact criteria distance does not exceed 160m, there will be no impact at BLB1 from incidents at BLB2. Hence, impacts at BLB1 from incidents at BLB2 have not been carried forward for further analysis.

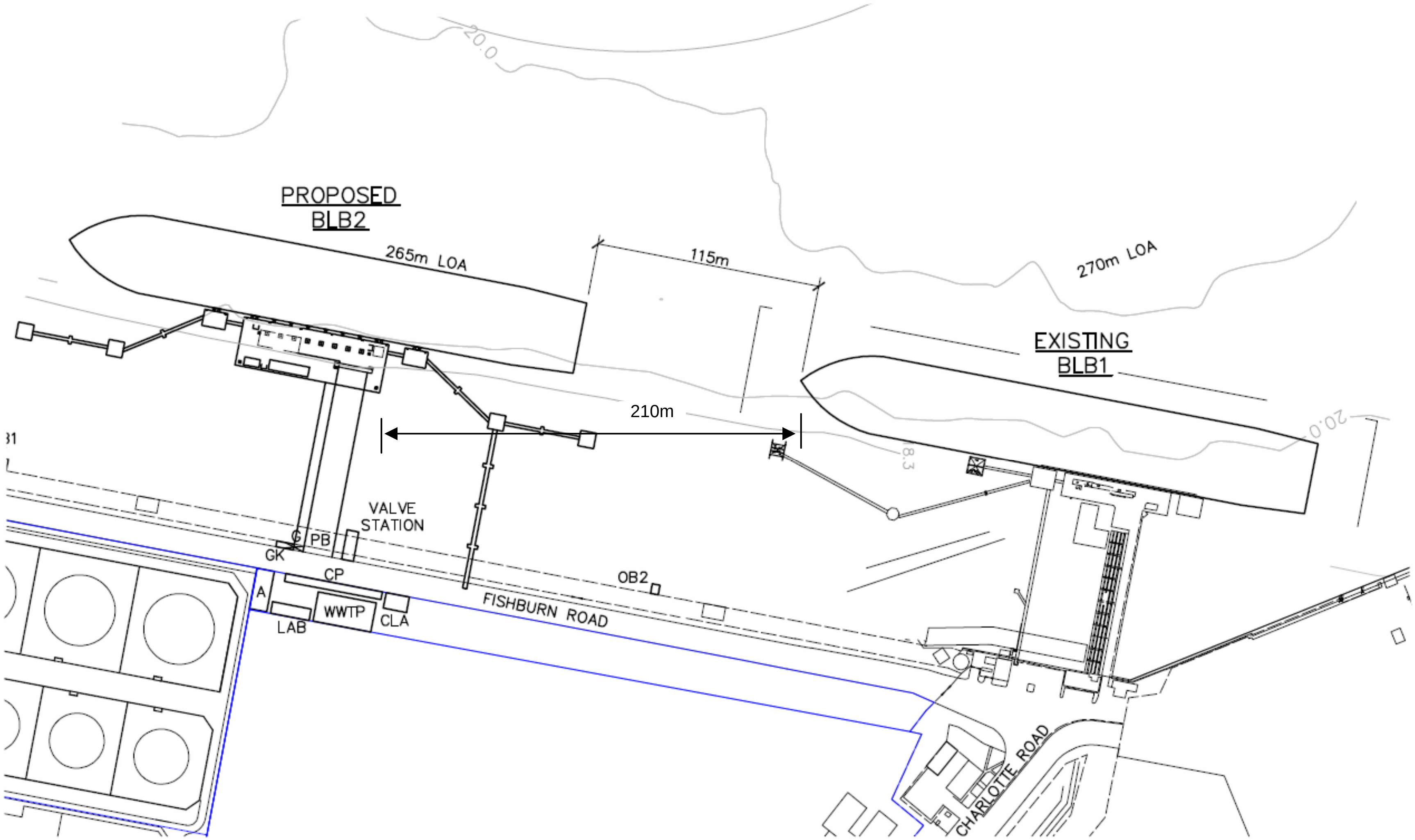

Figure 5-2 Separation Distance BLB1 to BLB2

6. FREQUENCY ANALYSIS

6.1 Incidents Carried Forward for Frequency Analysis

The consequence analysis was conducted to identify those incidents that had the potential to impact the existing fatality contours detailed in the Port Botany Land Use Planning Safety Study (Ref.1). The analysis identified a number of incidents that could result in increases to the contours, should the risks exceed those published in the Port Botany study (Ref.1).

Those incidents carried forward for frequency analysis are:

- Environmental Impact – flexible hose failure (chemical transfer);
- Jet fire – MLA catastrophic failure (LPG);
- Flash Fire – MLA catastrophic failure (LPG);
- Jet Fire – flange leak isolating valve station (LPG);
- Jet Fire – valve leak isolating valve station (LPG);
- Flash Fire – flange leak isolating valve station (LPG);
- Flash Fire – valve leak isolating valve station (LPG);
- Pool Fire – flange leak isolating valve station (flammable/combustible liquid); and
- Pool Fire – valve leak isolating valve station (flammable/combustible liquid).

The Port Botany Land Use Safety Study (Ref.1) lists a number of failure frequencies that have been used as the basis for the study. To ensure the results of the BLB2 risk analysis is consistent with the outcomes of the existing study (Ref.1), the Port Botany study frequency data will be used in the analysis below.

6.2 Environmental Impact – Flexible Hose Failure

Chemicals will be transferred using a flexible hose system. A number of hoses will be connected together, by flanged joints, to establish the required hose length from the ship to the wharf connection. Releases of chemical from those sections of hose on the ship and wharf will not result in impact to the environment as these areas are bunded. However, releases where the hose passes over the water would result in environmental impact.

A review of the equipment failure data bases reveals that CCPS (Ref.14) publishes a flexible hose failure rate as 0.005 p.a. This failure frequency is based on general hose transfer operations whereby hoses are tested annually in accordance with the ADG (Ref.4) or IMDG (Ref.15). It is noted that for chemical transfer operations at the BLB, the hoses will be pressure tested prior to every transfer, including full test of the hose connection integrity. Hence, hoses at the BLB would be less likely to fail as they are tested more frequently. An estimate of the reduction in failure rate as a result of the increased testing frequency has been made based on the number of additional tests conducted per annum. The total number of deliveries of chemicals is planned for 31 per annum, hence, hoses are tested 31 times more frequently than for standard hoses tested under the requirements of the ADG (Ref.4) & IMDG (Ref.15). The reduction in failure rate as a result of the additional testing is assumed to be proportional to the number of tests. Therefore, the failure frequency of hoses at the BLB2 facility is:

F_f hoses = 0.005 x 1/31 = $1.6x10^{-4}$ p.a.

In the event of hose failure, the failed section of hose may not be in the area between the ship and wharf. Hence, for those releases on the ship and wharf areas, the spillage would be contained and there would be no impact to the environment. The hose is 30m long and the section between the wharf and ship is only small (about 5m). Hence, the probability of failure in the hose section over the water is 5/30 = 0.17.

In addition, the transfer operation is continually staffed by a ship and wharf operator. These operators keep continual watch over the transfer operation. In the event of signs of hose distress (i.e. wet patches, minor weeps at joints, etc.) the transfer is stopped and the hose replaced. Hence, in the event the operators fail to detect an impending failure, a leak/release may occur causing environmental impact. A review of the human error failure probability (i.e. failure of the operators to detect the impending leak) has been estimated using the HEART Human Error Data Base (Ref.17). The selected human error probability is 0.03, a miscellaneous human error probability.

Hence, the risk of release to the environment, based on a maximum of 8 hoses in use at one time is:

Environmental Impact Risk = 8 x 1.6x10-4 x 0.17 x 0.03 = $6.5x10^{-6}$p.a.

A review of the HIPAP No.4, "Risk Criteria for Land Use Safety Planning" (Ref.9), reveals that there are no published criteria for environmental risk. However, a review of HIPAP No.3 (Ref.16), Guidelines for Environmental Risk Assessment", indicates that assessment of risk impacts to the environment should use the guidelines listed in the other HIPAP documents, based on consequence and frequency. A review of the fatality risk for industrial areas (HIPAP No.4 – Ref. 9) indicates that the acceptable risk criterion is 50 chances in a million per year. By comparison the risk of chemical release and damage to the environment is 6.5 chances in a million per year. Taking into consideration the fact that the BLB2 is within an industrial zone, and the assessment form environmental impact is conservative, the risk is considered to be low and no further analysis is conducted for this incident.

6.3 Jet Fire – MLA Catastrophic Failure (LPG)

The BLB2 will be constructed with a single gas MLA. The BLB2 MLA is basically a 300mm diameter pipeline with a number of swivel joints. The MLA length (including associated pipework) is about 30m (conservative). The failure frequency for a 300mm pipeline rupture is given as 5.8x10-8/m.yr. Hence, the failure frequency of the MLA is estimated to be:

MLA Rupture = 30 x $5.8x10^{-8}$ = $1.74x10^{-6}$ p.a.

This is considered a reasonable failure frequency for the MLA, as there are a number of safety features installed on the MLAs such as weak connections and dry-break couplings and the ship-shore connection point, pre-use pressure test (i.e. prior to every transfer) at a higher pressure than the operating pressure, proximity detectors to identify when the arm moves out of the predetermined operating envelope (i.e. alarm and automatic shut down of isolation valves), continual monitoring by operators both on the wharf and ship and non-return valves in the delivery line. All these safety features reduce the likelihood and magnitude of any incident. Hence, the likelihood of a release for 60 seconds (see **Section 5.4.2** – Flash Fire) is very low, as indicated by the estimated release frequency.

In the event of a release, ignition may not occur at every release. Hence, the probability of jet fire is estimated by multiplying the release frequency by the ignition probability (immediate ignition). The ignition probabilities used in the Port Botany Study (Ref.1) are not published in the study document. Hence, alternative ignition probabilities have been sourced for this study. An ignition probability, for a large gas release, of 0.3 has been used in this study (Ref.8). This ignition probability covers both immediate and delayed ignitions. Hence, the probability of delayed ignition vs. immediate ignition has been equally divided for this study. The immediate ignition probability is therefore 0.15.

Hence, the jet fire frequency has been estimated to be:

Jet Fire Frequency (immediate ignition) = 1.74×10^{-6} x 0.15 = **2.6×10^{-7}p.a.**

This result is conservative, as no account of the intermittent use of the MLA is taken into consideration.

6.4 Flash Fire – MLA Catastrophic Failure (LPG)

In the event of a major release at the MLA, the gas will evaporate and if not immediate ignited, may form a gas cloud that could drift finding an ignition source at a distance and after a time. Ignition in this case would result in a flash fire. Section 6.2 estimated the delayed ignition probability to be 0.15. Hence, the flash fire frequency is estimated to be:

Flash Fire Frequency (delayed ignition) = release frequency x ignition probability
= 1.74×10^{-6} x 0.15 = **2.6×10^{-7}p.a.**

This result is conservative, as no account of the intermittent use of the MLA is taken into consideration.

6.5 Jet Fire – Flange Leak Isolating Valve Station (LPG)

In the event of a release at LPG flanges, in the isolating valve station, a jet fire could result. The fire frequency is the multiple of the flange leak frequency x the ignition probability. There are three main gas pipelines delivering LPG products to the various terminals (Elgas, Qenos and Origin). Based on three lines and three valves, there would be six flanges that could leak at the pipework isolating valve station.

The flange failure frequency, published in the Port Botany study, is 3.6x10-4 p.a. The study does not indicate whether the flange is installed with a spiral wound gasket (SWG) or plain compressed fibre gasket (CFG). The probability of leak from a SWG is less than that of a CFG, due to the gasket construction and installation methods. Hence, for this study, releases from SWGs have been selected to be one order of magnitude less than the standard CFG. The selected value is therefore 3.6x10-5p.a.

The ignition probability for an LPG leak from a flange has been selected as 0.01 (Ref.8). This is the total ignition probability and therefore the potential for immediate ignition vs. delayed ignition has been equally apportioned.

The jet fire frequency is a function of the release frequency per flange x the number of flanges x ignition probability. Hence, the jet fire frequency has been estimated to be:

Jet Fire Frequency (immediate ignition) = $3.6\text{x}10^{-5}$ x 6 x 0.005 = $1.1\text{x}10^{-6}$p.a.

The above release frequency is based on the continued use of the system 24 hours per day, 7 days per week. However, the BLB2 will only transfer LPG products for a portion of the time. The remainder of the time the liquid lines will be purged and rest empty.

BLB Management estimate the total number of LPG product ships using the BLB2 facility will be as shown in **Table 6-1**.

Table 6-1 Expected LPG Ship Arrivals for BLB2

Product	2010	2011	2012
LPG	40	41	42

The average number of LPG ships to attend the BPB2 will be around 41, however, for conservatism, 42 has been used in the analysis. Assuming a ship stays alongside for a 1 day (on average) to transfer the flammable liquids, the exposure period for which fire can occur is 42/356 = 0.12.

Hence, the jet fire frequency for a flange leak incident, including exposure is:

Jet Fire Frequency (immediate ignition including exposure) = $1.1\text{x}10^{-6}$ x 0.12
= **$1.3\text{x}10^{-7}$p.a.**

6.6 Jet Fire – Valve Leak Isolating Valve Station (LPG)

In the event of a release at LPG valves, in the isolating valve station, a jet fire could result. The fire frequency is the multiple of the valve leak frequency x the ignition probability. There are three main gas pipelines delivering LPG products to the various terminals (Elgas, Qenos and Origin), hence, there are three valves that could leak at the pipework isolating valve station.

The valve failure frequency has not been published in the Port Botany study. Hence, an alternate valve failure frequency has been sourced. The offshore reliability data base (OREDA – Ref.11) provides information relating to valve leaks. A value of 0.14 external leaks per 10^6 hours (Taxonomy No. 4.3.5) has been selected for this study. This release frequency equates to $1.2x10^{-3}$ leaks p.a.

The ignition probability for an LPG leak from a valve has been selected as 0.01 (Ref.8). This is the total ignition probability and therefore the potential for immediate ignition vs. delayed ignition has been equally apportioned.

The jet fire frequency is a function of the release frequency per valve x the number of valve x ignition probability. Hence, the jet fire frequency has been estimated to be:

Jet Fire Frequency (immediate ignition) = $1.2x10^{-3}$ x 3 x 0.005 = $1.8x10^{-5}$p.a.

Using the same exposure probability as that developed in **Section 6.4**, the jet fire frequency for a valve leak is:

Jet Fire Frequency (immediate ignition including exposure) = $1.8x10^{-5}$ x 0.12
= **$2.16x10^{-6}$p.a.**

6.7 Flash Fire – Flange Leak Isolating Valve Station (LPG)

In the event of a release at LPG flanges, in the isolating valve station, a flash fire could result if the release does not ignite immediately. The fire frequency is the multiple of the flange leak frequency x number of flanges x the ignition probability. There are six LPG flanges in total at the pipeline isolating valve station (see **Section 6.5**) and the selected flange leak frequency is 3.6x10-5p.a. (see **Section 6.5**).

The ignition probability for an LPG leak from a flange has been selected as 0.01(Ref.8). This is the total ignition probability and therefore the potential for immediate ignition vs. delayed ignition has been equally apportioned.

The flash fire frequency is therefore estimated to be:

Flash Fire Frequency (delayed ignition) = $3.6x10^{-5}$ x 6 x 0.005 = $1.1x10^{-6}$p.a.

Using the same exposure probability as that developed in **Section 6.4**, the flash fire frequency for a flange leak is:

Flash Fire Frequency (immediate ignition including exposure) = $1.1x10^{-6}$ x 0.12

= **$1.3x10^{-7}$p.a.**

6.8 Flash Fire – Valve Leak Isolating Valve Station (LPG)

In the event of a release at LPG valves, in the isolating valve station, a flash fire could result if the release does not ignite immediately. The fire frequency is the multiple of the flange leak frequency x number of valves x the ignition probability. There are three LPG valves in total at the pipeline isolating valve station (see **Section 6.6**) and the selected valve leak frequency is 1.2x10-3p.a. (see **Section 6.6**).

The ignition probability for an LPG leak from a valve has been selected as 0.01(Ref.8). This is the total ignition probability and therefore the potential for immediate ignition vs. delayed ignition has been equally apportioned.

The flash fire frequency is therefore estimated to be:

Flash Fire Frequency (delayed ignition) = $1.2x10^{-3}$ x 3 x 0.005 = $1.8x10^{-5}$p.a.

Using the same exposure probability as that developed in **Section 6.5**, the flash fire frequency for a valve leak is:

Flash Fire Frequency (immediate ignition including exposure) = $1.8x10^{-5}$ x 0.12
= **$2.16x10^{-6}$p.a.**

6.9 Pool Fire – Flange Leak Isolating Valve Station (flammable/combustible liquid)

In the event of a release of flammable/combustible liquid from a flange, at the pipeline valve isolation station, the leak will accumulate in the valve pit and, if ignited would result in a pool fire. The frequency of fire is a function of the release frequency x the number of flanges x ignition probability.

There are six petroleum product pipelines and six chemical pipelines from the wharf to the various storage areas. Hence, each line has a valve and two flanges, however it is noted that chemical transfers will not involve chemicals with flammable/combustible characteristics on every occasion. The flange leak frequency has been selected as 3.6x10-4 p.a. (Ref.1). The probability of ignition in the event of a leak has been selected as 0.01. Based on a conservative estimate that 50% of the chemical products transferred have a sub-risk of Class 3/C1, the pool fire frequency for each product pipeline is estimated to be:

Ff_{pool} (flammable/combustible liquid flange leak) = $3.6x10^{-4}$ x 12 x 0.01 = $4.32x10^{-5}$p.a.

Ff_{pool} (chemical Class 3/C1 liquid flange leak) = $3.6x10^{-4}$ x 12 x 0.01 x0.5 = $2.16x10^{-5}$p.a.

The above release frequencies are based on the continued use of the system 24 hours per day, 7 days per week. However, the BLB2 will only transfer flammable/combustible & chemical liquids for a portion of the time. The remainder of the time the liquid lines will be purged and rest empty.

BLB Management estimate the total number of flammable/combustible & chemical liquid ships using the BLB2 facility will be as shown in **Table 6-2**.

Table 6-2 Expected Petroleum & Biodiesel Ship Arrivals for BLB2

Product	**2010**	**2011**	**2012**
Petroleum	32	35	35
Biodiesel	25	38	38
Total	57	73	73
Chemical	30	31	31

The average number of flammable and combustible liquids ships to attend the BLB2 will be around 68, however, for conservatism, 73 has been used in the analysis. Assuming a ship stays alongside for two days to transfer the flammable liquids, the exposure period for which fire can occur is 2x73/356 = 0.4. For conservatism, the number of chemical ships berthing and the BLB2 has been selected as 31. The exposure period, based on a 2 day attendance is 2 x 31/365 = 0.17.

Hence, the fire frequencies including exposure for the flammable/combustible and chemical liquid releases at the valve pit are:

Ff_{pool} (Class 3/C1 flange leak including exposure) = $4.32 \times 10^{-5} \times 0.4 =$ **1.7×10^{-5}p.a.**

Ff_{pool} (Chem. Class 3/C1 flange leak including exposure) = $2.16 \times 10^{-5} \times 0.17 =$ **3.6×10^{-6}p.a.**

The total frequency of fire in the valve pit, due to flange releases is the summation of the two frequencies, therefore combined frequency is:

Ff_{pool} (Class 3/C1 & Chemicals) = $1.7 \times 10^{-5} + 3.6 \times 10^{-6} = 2.06 \times 10^{-5}$

6.10 Pool Fire – Valve Leak Isolating Valve Station (flam./ comb. liquid)

In the event of a release of flammable/combustible liquid from a valve, at the pipeline valve isolation station, the leak will accumulate in the valve pit and, if ignited would result in a pool fire. The frequency of fire is a function of the release frequency x the number of valves x ignition probability.

There are six petroleum product pipelines and six chemical pipelines from the wharf to the various storage areas. Hence, there are six petroleum and six chemical valves from which leaks could occur. The valve leak frequency has been selected as 1.2x10-3 p.a. (see **Section 6.8**). The probability of ignition in the event of a leak has been selected as 0.01. As for the chemical flange frequency estimates, the chemicals with a flammable/combustible nature will not be transferred on every delivery occasion. It has been conservatively estimated that 50% of the products transferred will be Class 3/C1. Hence, the pool fire frequency for the two valve sets is estimated to be:

Ff_{pool} (Class 3/C1 valve) = 1.2×10^{-3} x 6 x 0.01 = 7.2×10^{-5}p.a.

Ff_{pool} (flammable/combustible chemical valve) = 1.2×10^{-3} x 6 x 0.01 x 0.5 = 3.6×10^{-5}p.a.

Similar to the flange assessment, conducted in **Section 6.9**, the flammable liquid and chemical pipelines are only used part of the time. Using the same values estimated in **Section 6.9**, the pool fire frequency is modified to cater for the proportional use of the pipelines. The fire frequencies for valve leaks, including exposure for the flammable/combustible and chemical liquid releases at the valve pit are:

Ffpool (Class 3/C1 flange leak including exposure) = 7.2x10-5 x 0.4 = **6.8x10^{-6}p.a.**

Ffpool (Chem. Class 3/C1 flange leak including exposure) = 3.6x10-5 x 0.17 = **6.1x10^{-6}p.a.**

The total frequency of fire in the valve pit, due to valve releases is the summation of the two frequencies, therefore combined frequency is:

Ffpool (Class 3/C1 & Chemicals) = 6.8x10-5 + 6.1x10-6 = 1.3×10^{-5}

7. RISK ANALYSIS & ASSESSMENT

7.1 Summary of Incident Frequencies and Fatality Probabilities

Sections 5 and **6** assessed incident consequences and frequencies. The combination of these provides an assessment of the incident risk. **Table 7-1** summaries the results of the fatality probability and incident frequency for those incidents carried forward for risk analysis.

Table 7-1 Summary of Fatality Probability, Incident Frequency and Risk Results

Incident	Fatality Probability[1]	Incident Frequency[2]	Risk[3] (pmpy)
Jet Fire-MLA Rupture (LPG)	1	$2.6x10^{-7}$p.a.	0.26
Flash Fire – MLA Rupture (LPG)	1	$2.6x10^{-7}$ p.a.	0.26
Jet Fire – flange leak isolating valve station (LPG)	0.35	$1.3x10^{-7}$ p.a.	0.045
Jet Fire – valve leak isolating valve station (LPG)	0.35	$2.16x10^{-6}$ p.a.	0.76
Flash Fire – flange leak isolating valve station (LPG)	1	$1.3x10^{-7}$ p.a.	0.13
Flash Fire – valve leak isolating valve station (LPG)	1	$2.16x10^{-6}$ p.a.	2.16
Pool Fire – flange leak isolation valve station (Flammable/Combustible Liquid)	0.48	$2.06x10^{-5}$ p.a.	10
Pool Fire – valve isolation valve station (Flammable/Combustible Liquid)	0.48	$1.3x10^{-5}$ p.a.	6.24

Notes: 1. see **Table 5-1**
2. Summarised from Section 6
3. Multiple of Fatality probability and incident frequency (per million per year – pmpy)

7.2 Assessment of Risks and Impact on Existing Risk Contours

The risk analysis has identified two main areas where the risk impacts may occur:

- The BLB2 MLA area on the wharf deck; and
- The pipeline isolating valve station located on the shoreline adjacent to the road.

The cumulative risks at each location are the summation of the individual risk events for each incident at that location. The assessment of cumulative risks and the impact on the existing contours (Ref.1) is conducted in the following sections.

7.2.1 Cumulative Risks for Incidents at the MLA

The two incidents described in **Table 7-1**, relating to the MLA risks, each have a risk of 0.26pmpy. Hence, the total risk (cumulative) is 0.26 x 2 = 0.52pmpy. This occurs at the existing 50pmpy contour that currently surrounds the proposed BLB2 facility in the Port Botany study (Ref.1). Hence, there would be negligible impact on the existing 50pmpy contour or the 1pmpy contour a further 30m beyond the 50pmpy contour.

In addition to the impact on the existing risk contours, there is a potential for the risk at the adjacent facilities to the BLB2 to exceed the risk criteria. The closest adjacent facility to the BLB2 wharf is the Elgas gas storage facility to the east, which is located about 120m from the BLB2 wharf facilities. The individual risk at the adjacent Elgas gas storage facility, as a result of incidents at the BLB2 wharf, is therefore below the 1pmpy and as the Elgas gas storage facility is an industrial site, the acceptable risk criteria is 50pmpy. Hence, as this criterion is not exceeded, the BLB2 facility meets the acceptable (published) risk criteria.

7.2.2 Cumulative Risks for Incidents at the Pipeline Isolating Valve Station

There were six incidents identified at the pipeline isolating valve station. The cumulative risk is the summation of the risk values in **Table 7-1,** which is 19.3pmpy. This risk impact occurs at the existing 50pmpy contour that currently surrounds the BLB2 facility in the Port Botany study (Ref.1). Hence, there would be no increase to the existing 50pmpy contour or the 1pmpy contour a further 130m into Botany Bay.

In addition to the impact on the existing risk contours, there is a potential for the risk at the adjacent facilities to the BLB2 to exceed the risk criteria. The closest adjacent facility to the pipeline valve station is the Elgas gas storage facility to the east, the boundary of which is located about 20m from the pipeline valve station. The individual risk at the adjacent Elgas gas storage facility is less than 19.3pmpy. As the Elgas gas storage facility is an industrial site, the acceptable risk criterion is 50pmpy. Hence, as this criterion is not exceeded, the pipeline valve station facility meets the acceptable (published) risk criteria.

8. REFERENCES

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Appendix A Hazard Identification Table

BLB Hazard Analysis

Area/Section	Hazard Cause	Hazard Consequence	Safeguards
Chemical Deliveries and Transfers			
Ship mooring	Ship strikes wharf at excessive speed	Potential to damage ships hull resulting in release	- Ship is moored using tugs - Pilot used to bring ship alongside - Fixed fenders used on the wharf - Double hull (liquid not in contact with outer hull)
Moored Ship	Passing ship strikes the moored ship	Potential to damage ships hull resulting in release	- Double hull (liquid not in contact with outer hull) - Marine exclusion zone (no unauthorised vessels - Low impact (low speed of operations) - Ships under tug and pilot control
Chemical hoses (150mm ID)	Coupling failure (i.e. flexible hose joints/ flanges)	Release of chemical from joint	- Bolted flanges - Annual testing of hoses/joints (new gaskets used at each transfer) - Pressure test with nitrogen prior to each use (800kPa) - Operation of hoses <700kPa - Start-up procedure to monitor pressuring of hoses including leak detection - Operator in attendance during full transfer (PPE available but not worn) - Operators in full radio communication with the wharf and shore operations - Manual shut down valves at each end - Loss is limited by hose length and reaction time - Operator dedicated to monitoring of all equipment during transfer

Area/Section	Hazard Cause	Hazard Consequence	Safeguards
			(leak detection) - Ships deck catchment (scuppers plugged) - Wharf is bunded with a 200mm bund wall all round.
Chemical hoses	Hose split/failure	Release of chemical from hose	- Annual testing of hoses/joints - Pressure test with nitrogen prior to each use (800kPa) - Operation of hoses <700kPa - Start-up procedure to monitor pressuring of hoses including leak detection - Operator in attendance during full transfer (PPE available but not worn) - Operators in full radio communication with the wharf and shore operations - Manual shut down valves at each end - Loss is limited by hose length and reaction time - Operator dedicated to monitoring of all equipment during transfer (leak detection) - Ships deck catchment (scuppers plugged) - Wharf is bunded with a 200mm bund wall all round.
Pipeline	Pipeline corrosion Leaks at flange locations (MLA, isolation valve pit)	Release of chemical from pipeline or flanges	- Fully welded pipeline along transfer route (pipeline joints are minimised) - Bunded deck on wharf - Containment pit around the pipe isolation valves (onshore) - Hydrostatic testing of pipes at commissioning and every 2 years (or when maintenance is performed on pipelines)

Area/Section	Hazard Cause	Hazard Consequence	Safeguards
			- Pipes are maintained empty & liquid free between transfers - Operator monitors operations during transfer (leak monitoring of pipelines) - Spiral wound gaskets (SWG) used throughout the pipeline connection points
Chemical Hoses	Ship securing lines fails	Ship moves away from wharf and hoses coupling parts – release of chemical	- Transfer ceases at wind speeds >35kph (hoses isolated) - Operators (marine) - Wind warning system from Bureau of Meteorology - Transfers cease when lightning occurs - Predominant winds are "on to the wharf" (ship is blown on to and not off the wharf - Securing lines are designed to secure against normal passing ships (i.e. waves generated in the bay) - Tug is on 24 hour call in adjacent dock area (Brotherson Dock)
Gas Delivery and Transfer			
Marine Loading Arm	Ship moves away from wharf – securing line failure	Limited gas release: - immediate ignition & jet fire - delayed ignition and flash fire	- MLA is hard piped - Arm movement outside "envelope" causes alarms and shuts down (ESD) and disconnects - Bolted connections from MLA to ship - Connections are pressure tested to 800kPa (nitrogen), leaks monitored - Start up procedure including slow pressure and monitoring - Operator on board ship

Area/Section	Hazard Cause	Hazard Consequence	Safeguards
			- MLA is monitored and controlled from a central control room with SCADA - ESD on wharf (at base of MLA) - Dry break & weak coupling at MLA connection to the ship - All equipment is classified to AS60079 (Hazardous Area Classification) - Fire Monitors located on the wharf (remote control) - Fire water pumps (diesel duty/stand-by)
Pipelines	Pipeline corrosion Leaks at flanges and valves	Leak, gas release: - immediate ignition & jet fire - delayed ignition and flash fire	- Fully welded pipeline along transfer route (only one isolation valve along the route, pipeline joints are minimised) - Bunded deck on wharf - Containment pit around the pipe isolation valves (onshore) - Hydrostatic testing of pipes at commissioning and every 2 years (or when maintenance is performed on pipelines) - Pipes are maintained empty & liquid free between transfers - Operator monitors operations during transfer (leak monitoring of pipelines) - SWGs used throughout the LPG system (i.e. at all joints)
Flammable & Combustible			
Marine Loading Arm	Ship moves away from wharf – securing line failure	Limited liquid release – potential pollution to the bay	- MLA is hard piped - Arm movement outside “envelope” causes alarms and shuts down (ESD) and disconnects - Bolted connections from MLA to ship

Area/Section	Hazard Cause	Hazard Consequence	Safeguards
			- Connections are pressure tested to 900kPa (nitrogen), leaks monitored - Start up procedure including slow pressure and monitoring - Operator (ships crew) on board ship during full transfer - MLA is monitored and controlled from a central control room with SCADA - ESD on wharf (at base of MLA) - Dry break & weak coupling at MLA connection to the ship - All equipment is classified to AS60079 (Hazardous Area Classification) - Bunded wharf - Ship deck is bunded (scuppers sealed) - Fuel spill emergency response plan & procedure
Marine Loading Arm	Ship moves away from wharf – securing line failure	Limited liquid release – ignition and pool fire	- MLA is hard piped - Arm movement outside “envelope” causes alarms and shuts down (ESD) and disconnects - Bolted connections from MLA to ship - Connections are pressure tested to 900kPa (nitrogen), leaks monitored - Start up procedure including slow pressure and monitoring - Operator (ships crew) on board ship during full transfer - MLA is monitored and controlled from a central control room with SCADA

Area/Section	Hazard Cause	Hazard Consequence	Safeguards
			- ESD on wharf (at base of MLA) - Dry break & weak coupling at MLA connection to the ship - All equipment is classified to AS60079 (Hazardous Area Classification) - Fire Monitors located on the wharf (remote control) - Fire water pumps – single pump provides 100% duty (diesel duty/stand-by)
Pipelines	Pipeline corrosion Leaks from flanges and valves	Liquid release – potential pollution to the bay	- Fully welded pipeline along transfer route (minimise joints and flanges) - Bunded deck on wharf - Containment pit around the pipe isolation valves (onshore) - Hydrostatic testing of pipes at commissioning and every 2 years (or when maintenance is performed on pipelines) - Pipes are maintained empty & liquid free between transfers - Operator monitors operations during transfer (leak monitoring of pipelines)
Emergency Response			
Wharf/Pipelines	Fire at the wharf/ pipelines	Requirement to apply fire water, which could carry contaminants into the bay	- Bunded area on the wharf deck (200mm high) - Containment pit for isolation valve station at the shoreline - Contaminant containment booms located at the shore line (i.e. deployed around ship and wharf) - Marine spill retention plan and procedures

Appendix B Consequence Analysis

B.1 INCIDENTS ASSESSED FOR CONSEQUENCE SEVERITY

Section 4 of the main report identified a number of incidents that could result in consequence impacts to the areas adjacent to the BLB2 facility. Those incidents for which a detailed consequence analysis is conducted are:

- LPG Transfer MLA Failure – leak/release, ignition and explosion/fire;
- LPG Pipeline Failure – leak/release, ignition and explosion/fire;
- Flammable/Combustible Liquid MLA Failure – leak/release, ignition and fire; and
- Flammable/Combustible Liquid Pipeline Failure - leak/release, ignition and fire.

Each incident has been assessed for consequence below.

B.2 MODELS USED IN THE ASSESSMENT

The modelling of incident consequences can involve complicated calculation requiring lengthy assessment. Hence, to assist in this analysis computer models have been developed to determine the impact of postulated incident scenarios. For this study the BP Cirrus model (Ref.7) has been used. CIRRUS is a compendium of physical models which can be used to predict the effects of a release of material, normally a hydrocarbon or chemical liquid or vapour. This model has been developed for use in the petroleum industry and is particularly applicable to the transfer and handling of flammable gases and liquids.

B.3 LPG Ship Connection Incidents

B.3.1 Release at the Ships Manifold Connection or MLA Flange

The MLA is connected to the ship's manifold by a bolted connection. A new spiral wound gasket (SWG) is used for this connection every time a transfer of LPG is performed. Flanges associated with the MLA are permanently connected using SWG, these flanges are not "disturbed" (i.e. disconnected) after each ship unloading operation. The system is tested using nitrogen, prior to each transfer operation. Hence, the potential for undetected leaks is low.

Notwithstanding this, a leak could occur at the flange face, resulting in initial slow release, with little impact and growing to a wire cut across the flange face. As the leak grows, the operator would detect the leak and commence shut down, Hence, the leak would be isolated and further release prevented. However, should an operator fail to isolate the leak (i.e. isolation valve fails, pump stop fails and manual valve isolation at the ships tank fails), the leak could continue. In the event of an immediate ignition, a jet fire would result. In the event of a delayed ignition the gas released could develop a cloud, which if ignited could result in a flash fire or explosion. Explosions will only occur where a cloud is confined. A review of the ships design and area surrounding the BLB indicates that there are no structures in the area beyond the immediate confines of the wharf and the only areas where an explosion could occur is the ship's deck or wharf itself. The cloud could be carried by the wind and drift beyond the unloading area where if ignited a flash fire could occur, which would flash back to the leak source where a jet fire would result. Each incident has been assessed below.

B.3.2 Release from Flange – Ships Manifold Connection or MLA Flange

The description above details the potential for a wire cut across the face of the flange, resulting in gas release. A conservative estimate has been made that the wire cut diameter would be 5mm. This would take considerable time to develop, hence, results would be conservative. The Cirrus model was run with the release diameter set a 5mm. **Figure B1** shows the results.

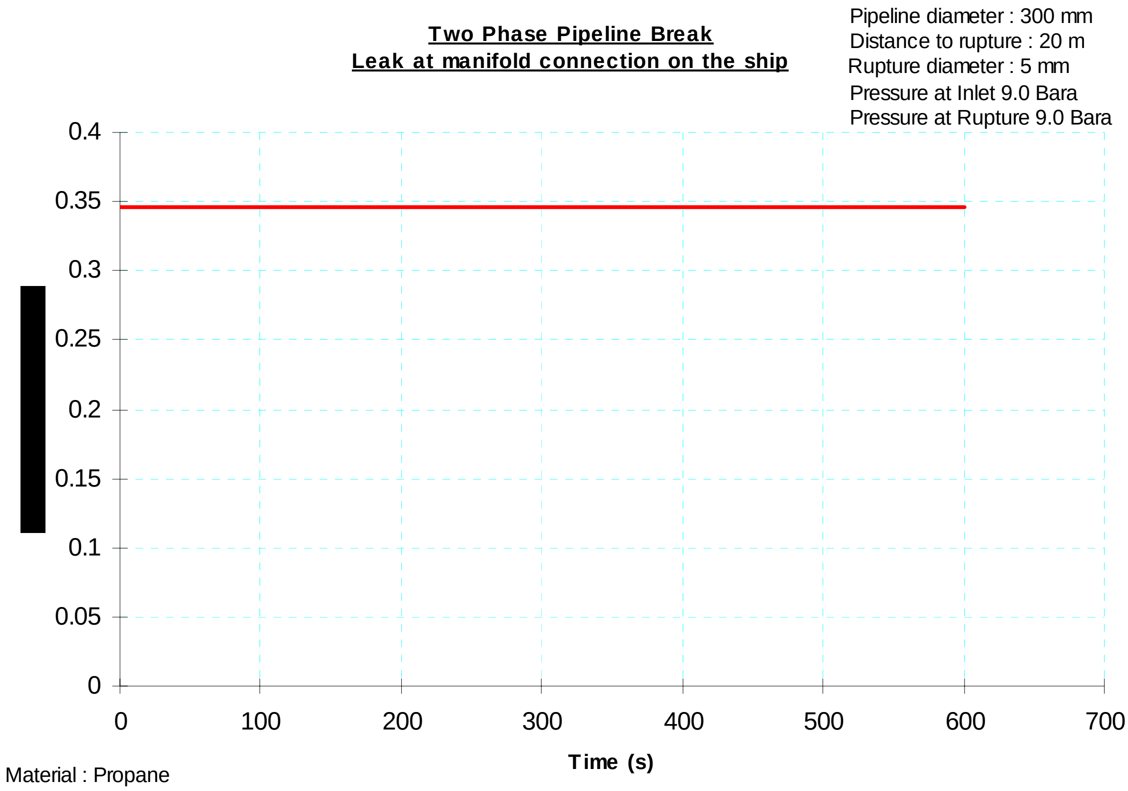

Figure B1 LPG Release from Flange – 5mm Dia. Hole

The release rate from the flange is estimated to be 0.35kg/s. This has been used in the following assessments.

B3.3 Jet Fire – Ships Manifold Incident

The Cirrus model was run using a gas release rate of 0.35kg/s. **Figure B2** shows the heat radiation impacts from the jet fire.

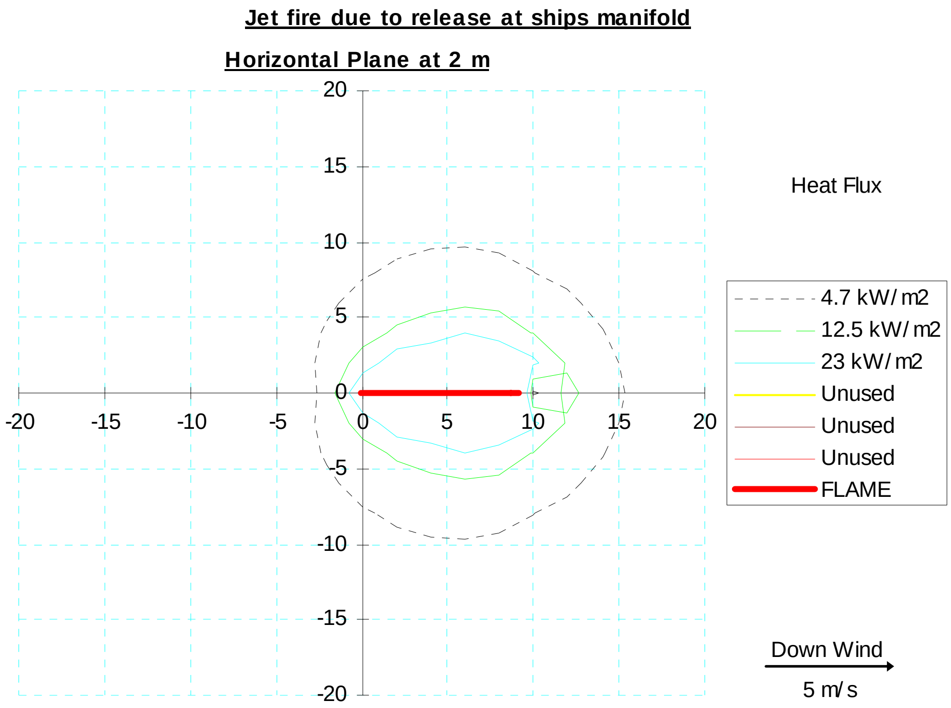

Figure B2 Heat Radiation Impacts Jet Fire at Ships Manifold Flange

It can be seen from **Figure B2** that the maximum impact distance to the heat radiation levels of interest is

- 4.7kW/m^2 = 10m.
- 12.5kW/m2 = 6m
- 23kW/m^2 = 4m

B3.4 Flash Fire – Ships Manifold Incident or MLA Flange Release

In the event a release does not immediately ignite, there is a potential for a gas cloud to build up. In the event the cloud drifts and finds an ignition source, a flash fire could result. In order to determine the cloud dimensions and distance to the furthest cloud limit, a dispersion analysis was performed for a range of wind weather conditions.

It is noted that dispersion of release gas is heavily influenced by the wind speed and weather conditions. Where the wind speed is high (5m/s) and there is bright sunshine, the gas will tend to disperse easily, hence, downwind concentrations of interest (i.e. Lower Flammable Limit, toxic concentrations) would be relatively close to the release source. However, where wind is light (1m/s) and conditions are cloudy, downwind concentrations of interest (i.e. LEL, toxic concentrations) would be relatively far from the source. A range of wind/weather conditions were selected for the LPG dispersion to identify the distance to the most conservative dispersion characteristics.

The Cirrus model was run with a variety of wind weather conditions to determine the distance to the LEL for the LPG. A conservative value of 2.1% of LPG in air was selected as the LEL for LPG. **Table B1** shows the results of the analysis.

Table B1 Distance to LEL for LPG Release at the Ships Manifold Dispersion for Selected Wind Weather Conditions

Wind Condition	Weather Condition	Distance to LEL 2.1% (m)
B	3	10
B	5	6
C	5	7
C	7	4
D	3	12
D	5	8
D	9	3
E	2	17
F	1.5	20

It can be seen from the analysis that the maximum impact distance for an LPG cloud in the LEL range, as a result of a joint failure at the ship manifold, is 20m at F1.5 wind/weather conditions.

B3.5 Explosion – Ships Manifold Incident or MLA Flange Release

In the event of a delayed ignition in F1.5 wind conditions, the explosion could generate a blast wave that could extend beyond the confines of the BLB. The explosion impact could affect the Port Botany Land use safety study contours (Ref.1). A review of a typical ships deck and layout (i.e. the location of the cloud on the ships deck, indicates that there is some confinement from pipework and equipment up to a height of 2m. The cloud dimensions are 50 x 10 x 0.4 high. Based on these dimensions the cloud confinement is estimated to be 100%.

Running the Cirrus explosion model with 100% cloud confinement results in explosion contours, as shown in **Figure B3**.

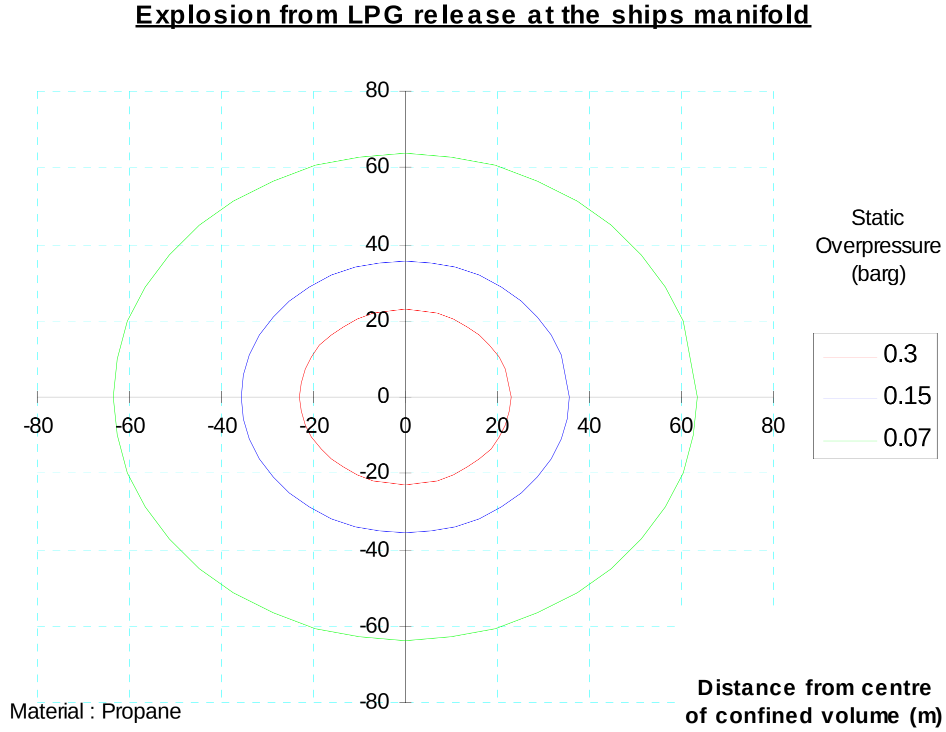

Figure B3 Explosion Overpressure Contours Gas Cloud as a Result of an LPG Leak at Ships Manifold

The distance to an explosion overpressure of 7kPa can be seen on **Figure B3** and is 62m.

B.4 MLA Catastrophic Incidents - LPG

The hazard analysis identified that in the event of small leaks at the MLA joints, there is a potential for the leaks to continue to grow, resulting in the release of gas at the swivel joints on the arm. Small leaks would not be initially detected, however as the leak grows, the release would become noticeable and operators would shut the transfer process down. Analysis of small leaks has been assessed in **Section B3**. Failure of instrument fittings could also cause releases. Instrument fittings have been estimated to have a pipe diameter of 5mm NB. Hence, leaks described in **Section B3** (5mm holes) would result in a release of about 0.35kg/s. This leak quantity is a considerable release and would be easily detected by operators, hence, the release conditions and consequences detailed in **Section B3**, would be applicable in the worst case leak incident at the MLA.

Notwithstanding this, an MLA failure (swivel joint) has been reviewed below to determine the worst case scenario should a swivel joint fail catastrophically. In this case the release diameter would be 300mm and the release would project into the BLB area.

B.4.1 Release at the MLA- Catastrophic Failure

The Cirrus program was run using an LPG release with a diameter of 300mm and a pipe length of 30m (i.e. estimated distance from the ship to the MLA failure point). The initial burst of LPG release settles quickly and a steady state release occurs almost immediately to a value of 82kg/s. It is estimated that the operator would respond immediately and close the delivery valves. The delivery valves are actuated and are 300mm nominal bore (NB). A valve of this size would take about 30 seconds to close, gradually shutting off the gas flow as the valve shuts. A conservative response time for the operator to access the emergency shut down button, and depress this button, has been estimated as 30 seconds. Total valve closure time is therefore estimated to be 60 second. Hence, a total of 60s x 82 kg/s would be released = 4,920kg (this is conservative as the flow rate would reduce as the gas isolation valve closes over the 30 second shut down period). There would be some initial flashing and the formation of a pool under the MLA from the material that did not flash. The evaporation rate from the pool was estimated using the Cirrus program based on a pool diameter of 32m (i.e. spread of LPG into the bunded wharf area). Based on this data, the average evaporation rate is 15kg/s for 328 seconds or 5.5 minutes.

B.4.2 Jet Fire at the MLA – Catastrophic Failure

The Cirrus model was run using a gas release rate of 82kg/s. **Figure B4** shows the heat radiation impacts from the jet fire.

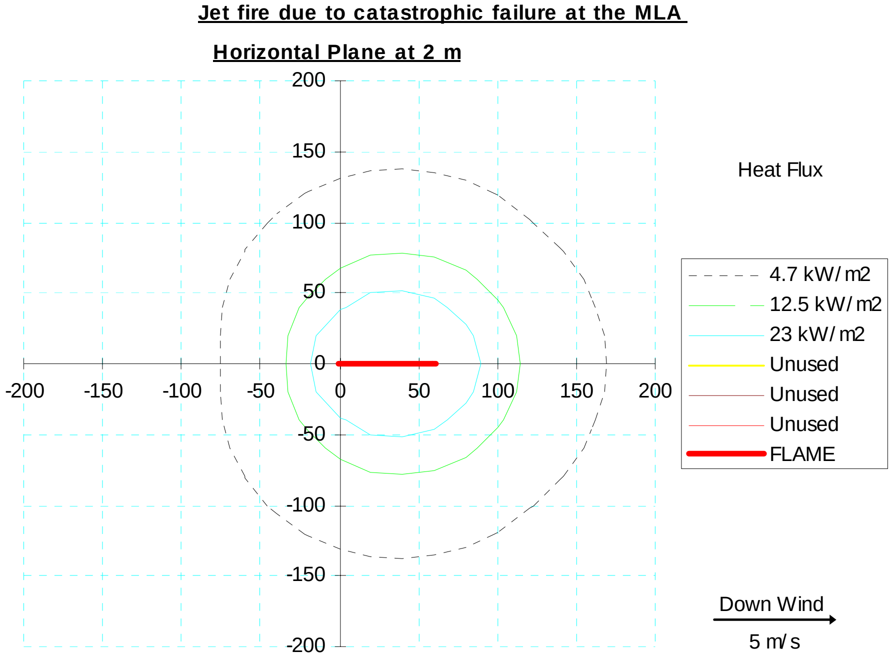

Figure B4 Heat Radiation Impacts Jet Fire at Ships Manifold Flange

It can be seen from **Figure B4** that the maximum impact distance to the heat radiation levels of interest is

- $4.7kW/m^2$ = 160m.
- 12.5kW/m2 = 120m
- $23kW/m^2$ = 80m

B.4.3 Flash Fire at the MLA – Catastrophic Failure

A gas dispersion was performed, using Cirrus, to determine the distance to the LEL. Release rate was 15kg/s. The distance to the LEL at selected wind weather conditions is shown in **Table B2**.

Table B2 Distance to LEL for LPG Release at the MLA Dispersion for Selected Wind Weather Conditions

Wind Condition	Weather Condition	Distance to LEL 2.1% (m)
B	3	90
B	5	60
C	5	80
C	7	75
D	3	150
D	5	100
D	9	120
E	2	195
F	1.5	160

It can be seen from the analysis that the maximum impact distance for an LPG cloud in the LEL range, as a result of a MLA catastrophic failure, is 195m at E2 wind/weather conditions.

B.4.4 Explosion at the MLA – Catastrophic Failure

In the event of a delayed ignition in E2 wind conditions, the explosion could generate a blast wave that could extend beyond the confines of the BLB. The explosion impact could affect the Port Botany Land use safety study contours (Ref.1). A review of the wharf deck layout (i.e. the location of the cloud on the wharf deck), indicates that there is some confinement from pipework and equipment up to a height of 2m. The cloud dimensions are 190 long x 150 wide x 1.2 high. Based on these dimensions and the wharf deck dimensions of 75mx25m, the cloud confinement is estimated to be 7%.

Running the Cirrus explosion model with 7% cloud confinement results in explosion contours as shown in **Figure B5**.

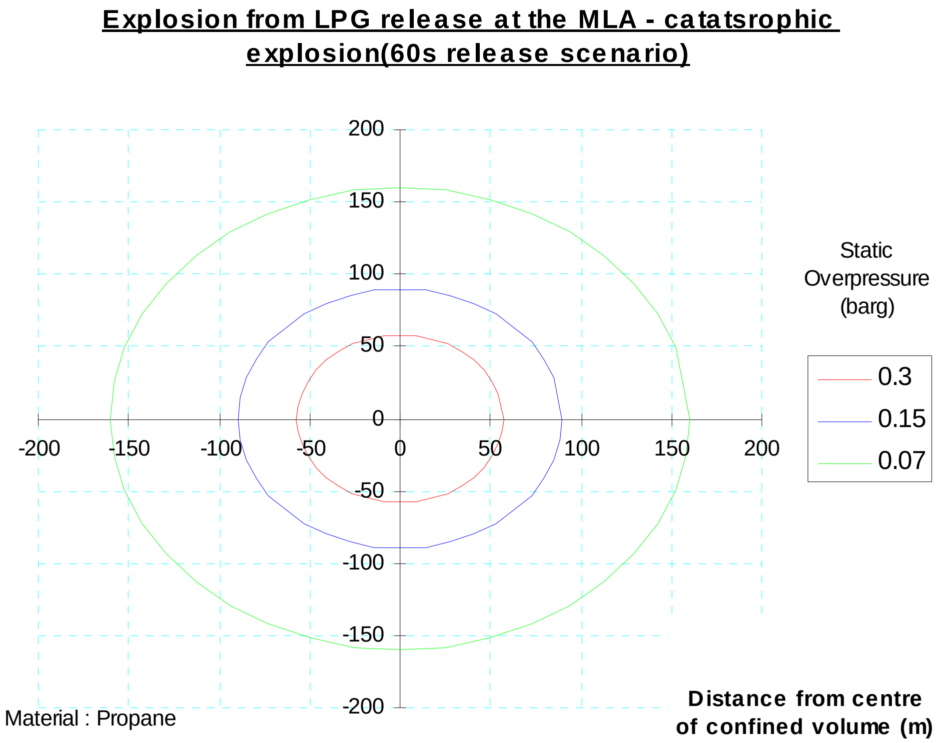

Figure B5 Explosion Overpressure Contours Gas Cloud as a Result of an LPG Catastrophic Release at the MLA

The distance to an explosion overpressure of 7kPa can be seen on **Figure B5** and is 160m.

B.5 Pipeline Incidents - LPG

The hazard identification section of the report identified that pipeline failures were a low risk due to the fully welded pipeline design, the commissioning testing and the regular hydrostatic testing (every two years). Hence, the main areas of release are identified to be valves and flanges.

B.5.1 Release at the Pipeline Valve

Flange releases will occur in the same manner as that described in **Section B3**. Hence, the data from this section may be used in the analysis of LPG flange releases in the pipeline. However, valves along the pipeline route may also leak at the valve stem. The valve stem is fitted with a gland, that prevents the release of LPG during normal operations. In the event of a gland failure, there is a potential for LPG to leak between the valve stem and body. This space is about 1mm wide and based on a valve stem of 25mm diameter (i.e. 300mm valve), the area of the annulus of 1mm around the stem is estimated by:

$$\text{Annulus Area} = \pi/4 \text{ x } (D_o^2 - D_i^2) = \pi/4 \text{ x } (0.026^2 - 0.025^2) = 8.2\text{x}10^{-5}\text{m}^2$$

The equivalent release diameter = $(4/\pi \text{ x } 8.2\text{x}10^{-5}) = 0.010$m

Based on similar operating conditions to those described for the flange release (Section B3.1.1) the release rate from a 10mm hole is estimated using the Cirrus model. The results of the analysis are shown in **Figure B6**.

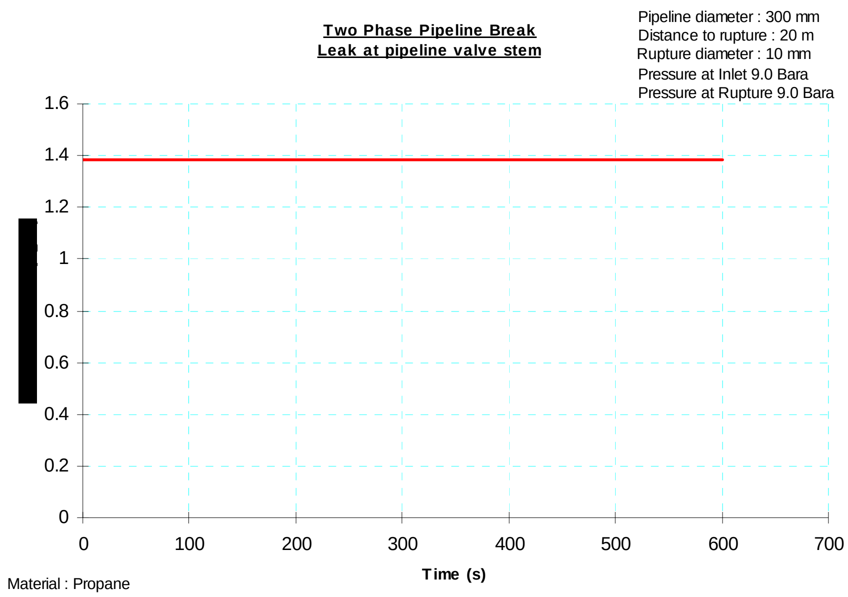

Figure B6 LPG Release from Valve Stem – 10mm Dia. Hole

The release rate from the valve stem is estimated to be 1.4kg/s. This has been used in the following assessments.

B.5.2 Jet Fire – Valve Leak Incident

The Cirrus model was run using a gas release rate of 1.4kg/s. **Figure B7** shows the heat radiation impacts from the jet fire.

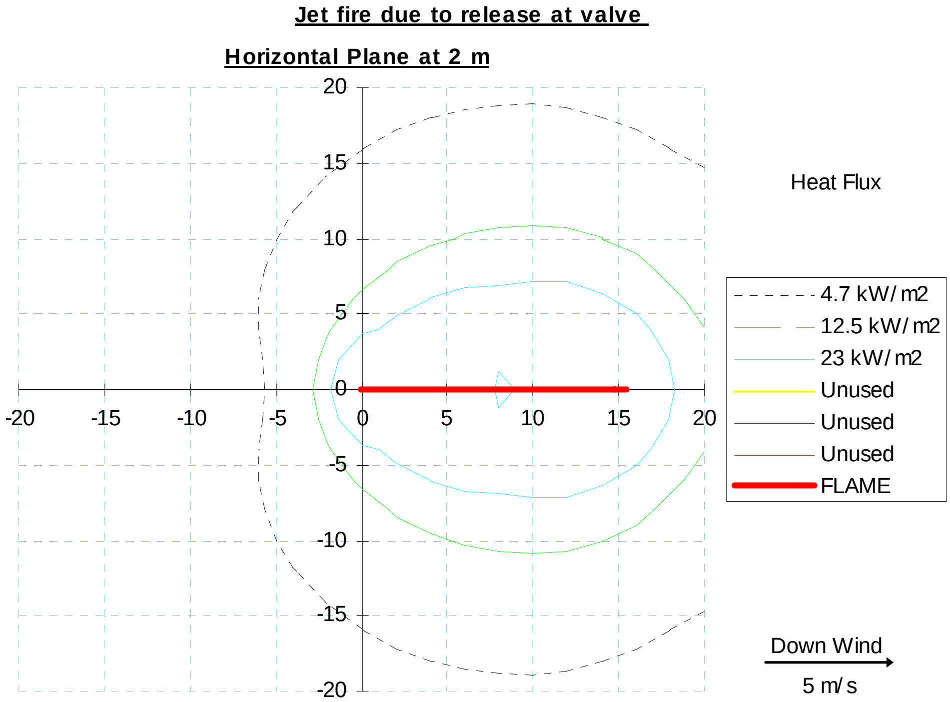

FIGURE B7

HEAT RADIATION IMPACTS JET FIRE DUE TO VALVE RELEASE

It can be seen from **Figure B7** that the maximum impact distance to the heat radiation levels of interest is

- 4.7kW/m^2 = 18m.
- 12.5kW/m2 = 10m
- 23kW/m^2 = 7m

B.5.3 Flash Fire – LPG Valve Leak Incident

As detailed in **Section B.3.4**, in the event a release does not immediately ignite, there is a potential for a gas cloud to build up. In the event the cloud drifts and finds an ignition source, a flash fire could result. In order to determine the cloud dimensions and distance to the furthest cloud limit, a dispersion analysis was performed for a range of wind weather conditions.

The Cirrus model was run with a variety of wind weather conditions to determine the distance to the LEL for the LPG. A conservative value of 2.1% of LPG in air was selected as the LEL for LPG. **Table B3** shows the results of the analysis.

Table B3 Distance to LEL for LPG Release at a Pipeline Valve Dispersion for Selected Wind Weather Conditions

Wind Condition	Weather Condition	Distance to LEL 2.1% (m)
B	3	25
B	5	17
C	5	20
C	7	16
D	3	32
D	5	21
D	9	15
E	2	38
F	1.5	44

It can be seen from the analysis that the maximum impact distance for an LPG cloud in the LEL range, as a result of a valve leak at the pipework valve station, is 44m at F1.5 wind/weather conditions.

B.5.4 Explosion – LPG Valve Leak Incident

In the event of a delayed ignition in F1.5 wind conditions, an explosion as a result of a leak at a valve could generate a blast wave that could extend beyond the confines of the BLB. The explosion impact could affect the Port Botany Land use safety study contours (Ref.1). A review of the pipeline layouts indicates that the pipelines are located at ground level up to a height of about 0.5m. The cloud dimensions are 20 x 120 x 0.4 high. Based on these dimensions, and the fact that the pipe corridor is about 20m wide, the cloud confinement is estimated to be 25%.

Running the Cirrus explosion model with 25% cloud confinement results in explosion contours, as shown in **Figure B8**.

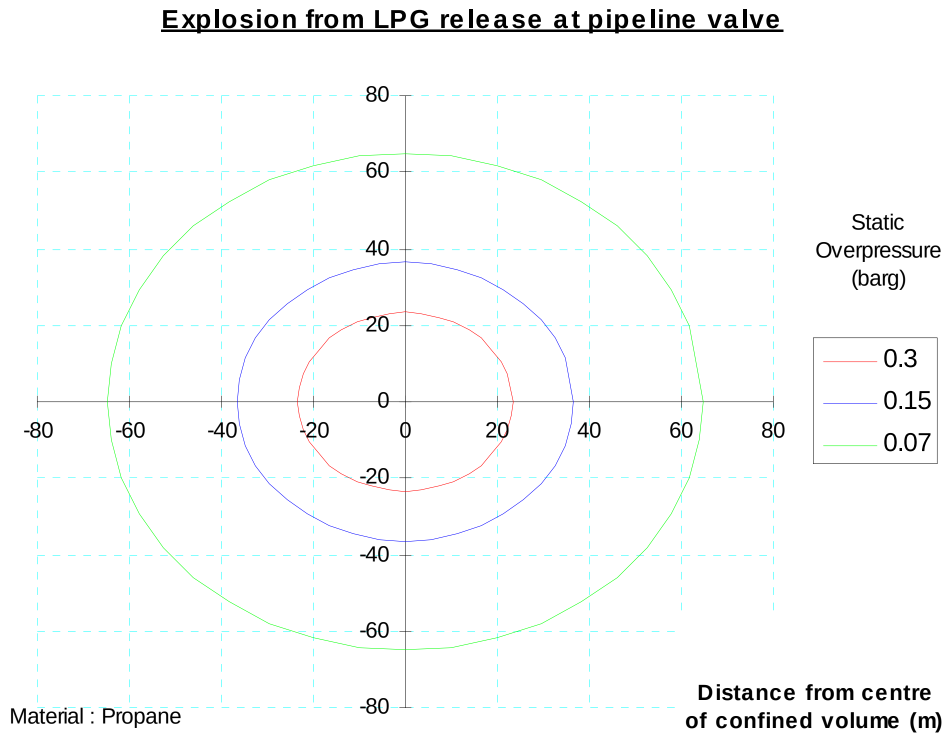

Figure B8 Explosion Overpressure Contours Gas Cloud as a Result of an LPG Leak at a Pipeline Valve

The distance to an explosion overpressure of 7kPa can be seen on **Figure B8** and is 62m.

B.6 Flammable/Combustible Liquid – Ship Connection Incident

B.6.1 Flammable Combustible Liquid Release Rate

Like the LPG loading arms, the flammable and combustible liquid loading arms will be connected to the ships manifold by a bolted connection. Flammable and combustible liquid connections will use compressed fibre gaskets to form a seal between the manifold and MLA flanges. Once connected the MLA and manifold connection will be tested to 800 kPa to identify any leaks prior to use.

Notwithstanding the pre-start leak tests, there is a potential for a gasket to fail, blowing out the compressed fibre section of the gasket between two flange bolts, however, this is unlikely. Nonetheless, an estimation of the quantity of leak that occurs from this event has been made.

Based on 300mm pipework and flanges, the space between the flange bolts are estimated to be 100mm (using 12 bolts a 400mm pitch circle diameter for the bolts). The gasket thickness between the flanges is 3mm. Hence, the release area is 0.100 x 0.003m2 = 0.0004m2. The equivalent release diameter for use in the Cirrus model is therefore D= (4/π x 0.0004)0.5 = 0.0195m or 19.5mm

The Cirrus model was used to estimate the liquid release rate. **Figure B9** shows the steady state release rate for the flammable/combustible liquid.

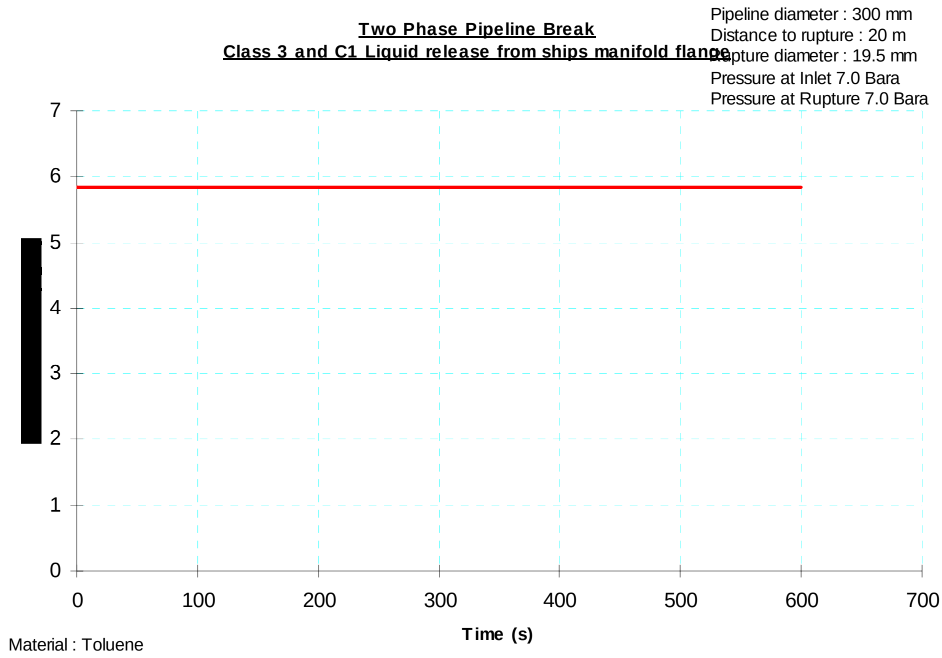

Figure B9 Flammable/Combustible Liquid Release Rate from a Flange Leak Ships Manifold Connection

The release rate for flammable/combustible liquids, from a 19.5mm hole, has been estimated to be 5.8kg/s.

B.6.2 Flammable Combustible Liquid Pool Diameter

In the unlikely event of a release of flammable/combustible liquid to the deck of the ship, the release would be identified immediately by the operator and the delivery valves closed. This would stop the release and prevent further flammable/combustible liquid from spilling to the deck. It has been conservatively assumed that it would take an operator about 60 seconds to isolate the valve, resulting in a total of 60s x 5.8kg/s = 348kg released to the deck. The average density of flammable and combustible liquid transferred at the BLB has been estimated to be 800kg/m3. Hence, the volume of flammable and combustible liquids released is 348/800 = 0.435 or 435 Litres.

The flammable/combustible liquid, released to the deck, would pool on the deck and be contained by the ships scuppers (which are plugged for the transfer operation). The spread of the pool would be unconfined and therefore based on a pool thickness of 5mm (Ref.8), the diameter of the pool, based on a volume of 218 Litres and a pool thickness of 0.005m, is:

Pool Diam. = $(4/\pi \times 0.435/0.005)^{0.5}$ = 10.5m

B.6.3 Flammable/Combustible Liquid Pool Fire Impacts – MLA Failure

To estimate the impacts of a fire on the ships deck, the Cirrus model was run using an unconfined pool of 10.5m diameter. The results of the analysis are shown in **Figure B10**.

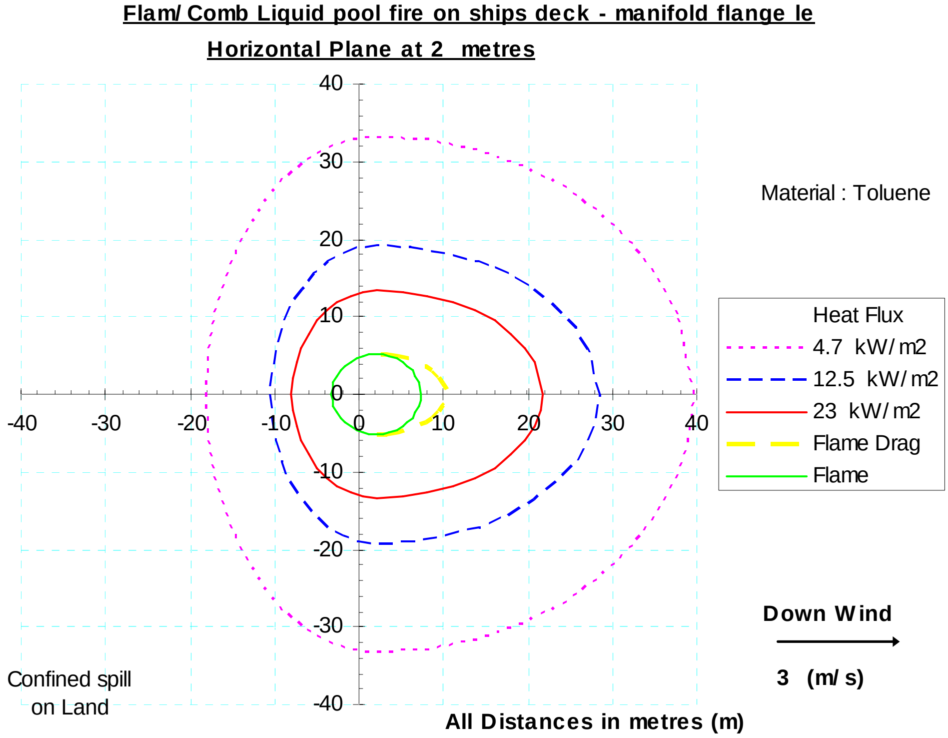

Figure B10 Flammable/Combustible Liquid Leak – Ships Manifold Connection Heat Radiation Contours

It can be seen from **Figure B10** that the maximum impact distance to the heat radiation levels of interest is:

- 4.7kW/m^2 = 40m.
- 12.5kW/m2 = 29m
- 23kW/m^2 = 22m

B.7 Flammable/Combustible Liquid – MLA Catastrophic Failure

B.7.1 Flammable Combustible Liquid Release Rate

The flammable and combustible liquid loading arms contain a number of swivel joints that permit the end of the arm to be located at the ships manifold, without placing stress on the arm components. In the event of a minor leak, the release quantities will be small and the operations will be shut down to repair the leak before continuing transfer. However, in the event of a swivel joint catastrophic failure, there is a potential for the flammable/ combustible liquid to escape via the full 300mm diameter hole.

Notwithstanding the pre-start leak tests, and the unlikely potential for this incident to occur, an assessment of release and pool fire consequences has been conducted.

Based on 300mm MLA pipework, a failure of the swivel joint would result in a full diameter release at 700kPa. These values have been used to determine the release rate of the flammable/combustible liquid for this incident.

The Cirrus model was used to estimate the liquid release rate. The steady state release rate for the flammable/combustible liquid release from a catastrophic failure of the MLA was estimated to be 80kg/s.

B.7.2 Flammable Combustible Liquid Pool Diameter

In the unlikely event of a release of flammable/combustible liquid from the MLA, the spill would fall to the deck of the wharf, where it would be contained by the wharf bunding. It has been conservatively assumed that it would take an operator about 60 seconds to isolate the valve, resulting in a total of 60s x 80kg/s = 4,800kg released to the deck. The average density of flammable and combustible liquid transferred at the BLB has been estimated to be 800kg/m3. Hence, the volume of flammable and combustible liquids released is 4,800/800 = 6m3.

The flammable/combustible liquid, released to the deck, would pool on the deck and be contained by the bunded sides of the wharf. The spread of the pool would be generally unconfined and therefore based on a pool thickness of 5mm (Ref.8), the diameter of the pool, based on a volume of 6m3 and a pool thickness of 0.005m, is:

$$\text{Pool Diam.} = (4/\pi \times 6/0.005)^{0.5} = 39\text{m.}$$

However, the wharf deck is only 31m wide (bund inside dimensions) and hence, the spread of liquid to 5mm deep would be:

$$V = 6m^3 = L \times 31 \times 0.005;\ \ L = 38.7, \text{ and an equivalent fire diameter is estimated by:}$$

$$D = ((38.7x32)x4/\pi)^{0.5} = 39.7\text{m}$$

B.7.3 Flammable/Combustible Liquid Pool Fire Impacts – MLA Catastrophic Failure

To estimate the impacts of a fire on the wharf deck, the Cirrus model was run using an unconfined pool of 39.7m diameter. The results of the analysis are shown in **Figure B11**.

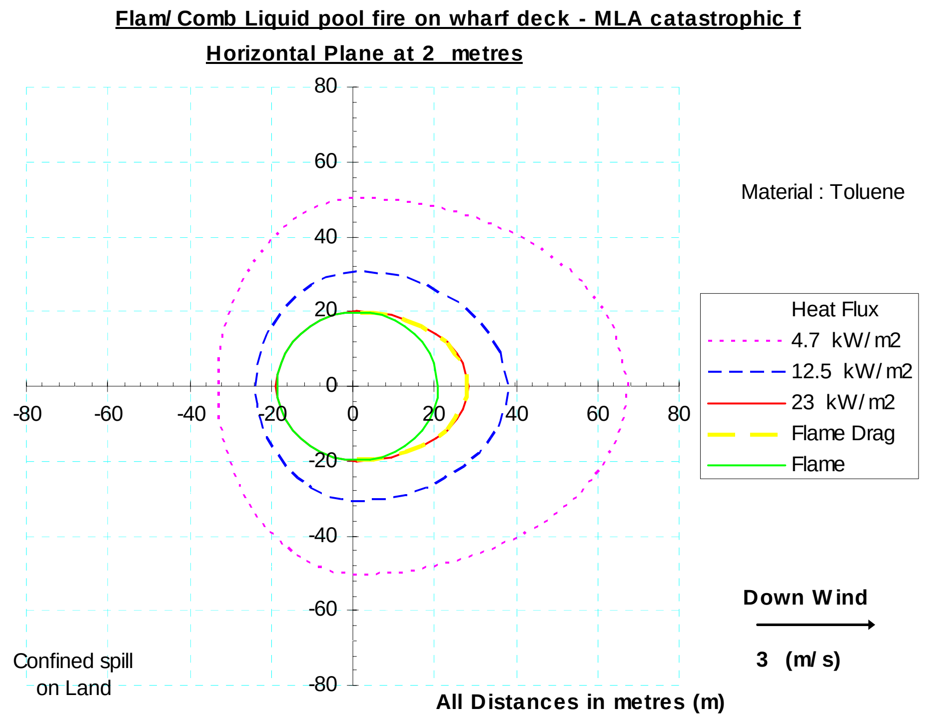

Figure B11 Flammable/Combustible Liquid Leak – MLA Catastrophic Failure Heat Radiation Contours

It can be seen from Figure B11 that the maximum impact distance to the heat radiation levels of interest is:

- 4.7kW/m^2 = 68m.
- 12.5kW/m^2 = 39m
- 23kW/m^2 = 24m

B.8 Pipeline Incidents – Flammable/Combustible Liquids

The hazard identification section of the report identified that pipeline failures were a low risk due to the fully welded pipeline design, the commissioning testing and the regular hydrostatic testing (every two years). Hence, the main areas of release are identified to be valves and flanges.

B.8.1 Release at the Pipeline Valve

Flange releases would occur in the same manner as that described in **Section B.6**. Hence, the data from this section may be used in the analysis of flammable combustible liquid flange releases in the pipeline. Flange release rates were estimated to be 5.8kg/s (see **Section B.6**).

However, valves along the pipeline route may also leak at the valve stem. The analysis of valve stem releases was conducted in **Section B.5.1** and the resultant equivalent release diameter for a valve stem leaks was estimated to be 10mm.

Based on similar operating conditions to those described for the flange release (**Section B.6.1**) the release rate from a 10mm hole is estimated using the Cirrus model. The results of the analysis are shown in **Figure B12**.

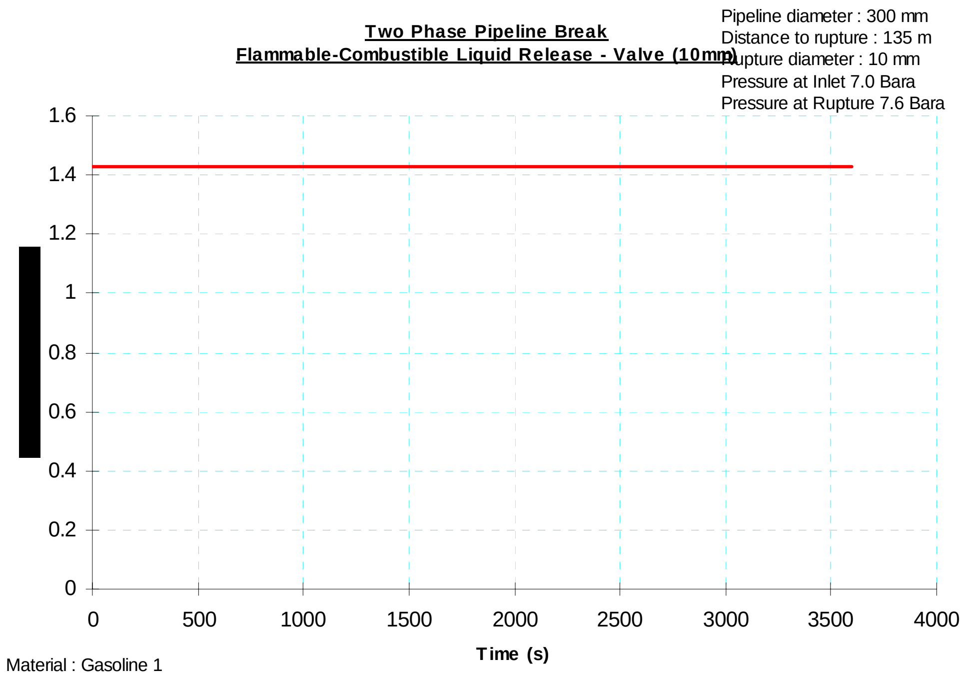

Figure B12 Flammable & Combustible Liquid Release Valve Stem – 10mm Dia. Hole

The release rate from the valve stem is estimated to be 1.45kg/s. This release rate along with the release rate for flanges (5.8kg/s) has been used in this assessment.

B.8.2 Flammable Combustible Liquid Pool Diameter – Valve Leak

In the unlikely event of a release of flammable/combustible liquid from a valve or flange on the wharf, the release would be identified by the operator and the transfer isolated immediately. The estimated release rate from the flange is 5.8kg/s and from a valve, 1.45kg/s. These release rates are significantly less than the impact from an MLA release of 80kg/s. Hence, for this analysis, the worst case incident has been estimated to be the MLA catastrophic failure and should this incident be identified to impact the Port Botany Risk contours (Ref.1), a review will be conducted to include the valve leak incident on the wharf.

A flange or valve leak in the main shoreline isolating pit could release flammable and combustible liquid to the ground or bay, however, the pipeline isolation valve area is constructed with a collection pit that contains any spillage. In the event the spill occurs in the pit, and is ignited, a pool fire will result radiating heat to the surrounding areas. As the pit contains any spills, the magnitude of the release is not the contributing factor to the size of the fire. This is governed by the pit dimensions.

The valve pit dimensions are 12m long by 5m wide (60m2). Hence, the equivalent pool diameter as a result of a fire in the pit is:

Pool Diam. = $(4/\pi \times 60)^{0.5}$ = 8.75m

B.8.3 Flammable/Combustible Liquid Pool Fire Impacts – Pipeline Isolation Valve Pit

To estimate the impacts of a fire on the areas adjacent to the valve pit (shore) from a valve leak and pool fire in the pit, the Cirrus model was run using a confined pool of 8.75m diameter. The results of the analysis are shown in **Figure B13**.

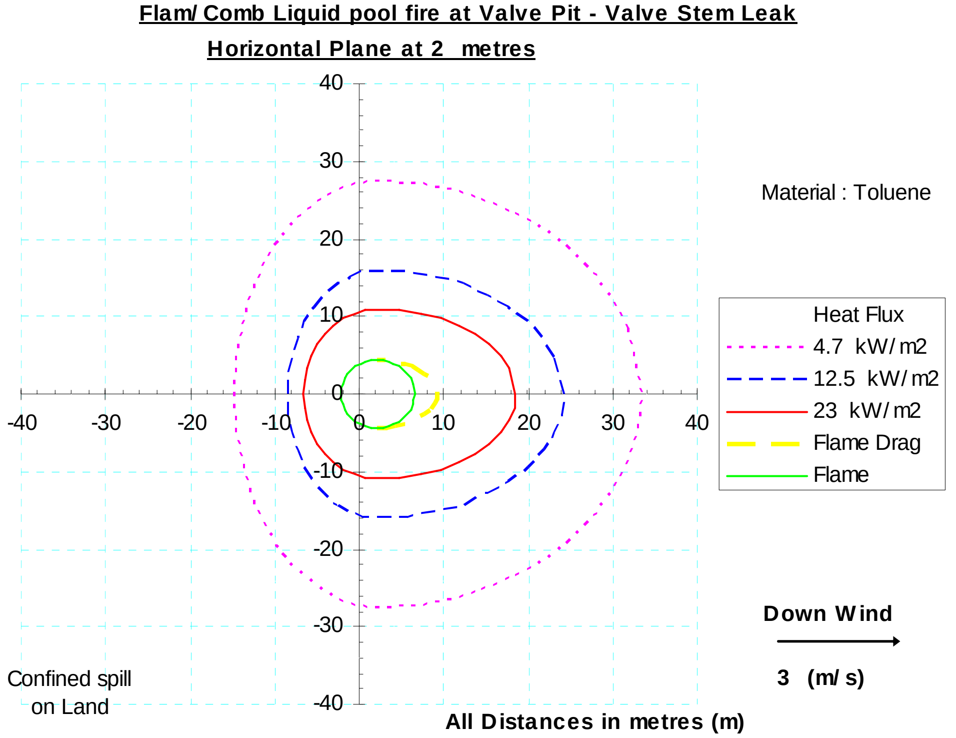

Figure B13 Flammable/Combustible Liquid Leak – Valve Leak at Shore Isolation Heat Radiation Contours

It can be seen from **Figure B13** that the maximum impact distance to the heat radiation levels of interest is:

- $4.7kW/m^2$ = 33m.
- $12.5kW/m^2$ = 24m
- $23kW/m^2$ = 18m

B.9 Flammable/Combustible Liquid Pool Fire Impacts – Flexible Hose Failure

The hazard analysis (**Section 4.2.4**) identified that in the event of a flexible hose rupture, the maximum flow rate from the hose would be 50 L/s. Hence, the worst case incident for hose failure would result in a maximum of 50L/s discharge to the wharf. In the event of a flexible hose rupture, the operator on the ship would immediately notify the pump room crew to stop the transfer pump and the operator would then isolate the transfer valve at the ships manifold. The pump stop sequence and isolation has been assumed to take up to 60 seconds, hence, the total discharge quantity would be 60 seconds x 50 L/s plus the quantity in the hose.

The quantity of liquid in a 150mm hose from ship to shore = the hose cross sectional area x the hose length. Assuming a hose length of 30m and a diameter of 150mm, the volume of liquid in the hose is:

Volume Liquid in the Hose = $\pi/4 \times 0.15^2 \times 30 = 0.53m^3$ or 530 Litres

Quantity release before isolation = 60 seconds x 50 L/s = $3m^3$ or 3,000 Litres

Total release = $2.3m^3$ or 3,530 Litres

The liquid released onto the wharf will spread in a pool to a thickness of 5mm (Ref.8, main report). Hence, the pool diameter is estimated by:

$$D = [(4x\pi) \times (3.53/0.005)]^{0.5} = 30m$$

It is noted that the wharf dimensions are 76m long x 32m wide, hence, the pool will spread to a full diameter of 30m without constriction by the wharf bunding.

To estimate the impacts of a fire on the areas surrounding the wharf, from a flexible hose failure and pool fire on the wharf, the Cirrus model was run using a confined pool of 30m diameter. The results of the analysis are shown in **Figure B14**.

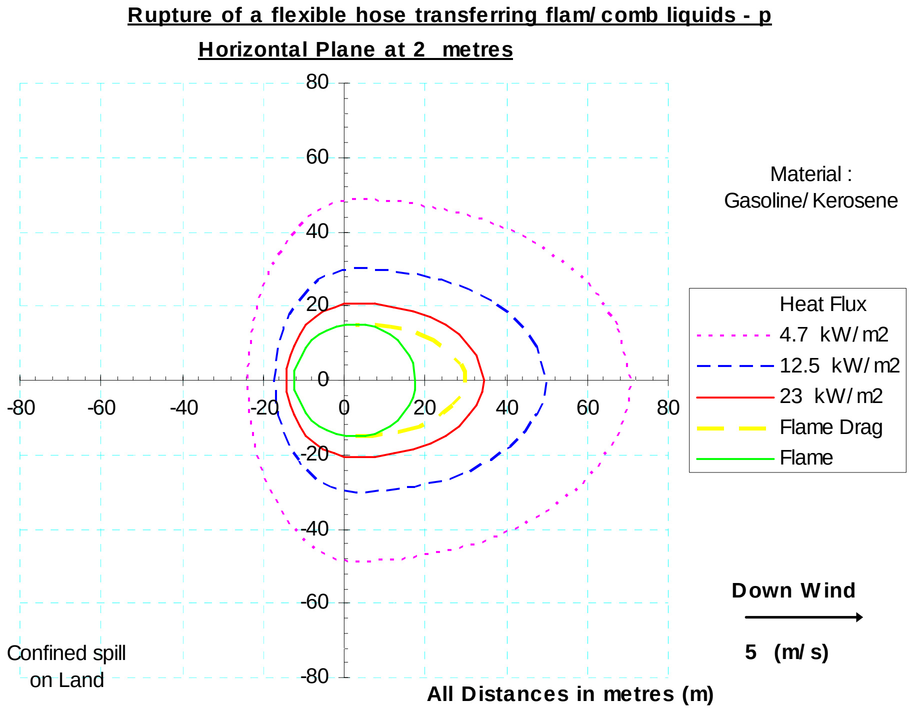

Figure B14 Flammable/Combustible Liquid Leak – Valve Leak at Shore Isolation Heat Radiation Contours

It can be seen from **Figure B14** that the maximum impact distance to the heat radiation levels of interest is:

- $4.7kW/m^2$ = 70m.
- $12.5kW/m^2$ = 50m
- $23kW/m^2$ = 33m

The heat radiation impact at 50m (50pmpy contour) is $12.5kW/m^2$.